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PSYCHOLOGICAL CONSIDERATIONS IN THE DESIGN OF TRAINING EQUIPMENT

ROBERT B. MILLER

THE AMERICAN INSTITUTE FOR RESEARCH

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FOREWORD

This report was prepared by the American Institute for Research under USAF Contract No. AF 33(616)-2080. The contract was initiated under Project 7197, "Human Engineering Factors in the Design of Training Equipment." The contract was administered by the Psychology Branch, Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, with Dr. Gordon A. Eckstrand, Chief, Trainer Research Section, Psychology Branch, acting as Project Scientist.

It is intended for use by engineers who design training equipment or assist in preparing the specifications for them, by psychologists and others who are concerned with the design of programs of training which use training devices and aids. It is possible that some instructors will be interested in at least some of the content, since the instructor is perhaps the most ubiquitous of all training devices available and may compensate for defects and exploit the assets of hardware used for training.

The purpose of this report is to assist those who specify, design, or use training devices to consider the human, psychological factors which determine the effectiveness of the devices. A number of rule of thumb recommendations are offered, usually in a condensed context of explanation. For a more extended treatment of most topics in this report, see the parent reports of which this is a digest. These parent reports are listed in the Preface.

The author is indebted to Dr. Eckstrand for suggestions on form of presentation and for careful editorial review and to Dr. Alan D. Swain especially for the material on the instructor's station. Dr. Swain is author of the parent report of which this instructor's station material is, in great part, a digest.

ABSTRACT

A training device is a machine whose purpose is to teach job skills which will transfer to operational situations. As such, the human factors involved in efficient learning and transfer of training are considerations essential to economy and training value of trainer design. The report presents a number of considerations and recommendations for trainer design under the following topics: I. Some principle concepts in learning and transfer of learning; II. Problems of physical simulation; III. Stage of learning and degree of physical simulation; IV. Knowledge of results and scoring; V. Recording procedures; VI. Proficiency measurement; VII. The design of the instructor's station; VIII. The trainer as demonstrator of principles; IX. Outline of steps in designing a training device.

This report is essentially a digest of previously published material by the author and by Dr. Alan D. Swain. It has been adapted for persons who may not have a professional background in psychology. The report is intended for those who participate in framing the requirements for training devices, designing them and, in lesser degree, for those who use them in training.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

A. M. Henderson, Col. USAF (MSC)

for JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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PREFACE

Several publications, currently available or anticipated in the near future, indicate the features of equipment and work environments that help or hinder a human operator to do a job. This report is intended to suppliment those publications and emphasizes those human properties and their matching environmental requirements which deal with his learning to do a job.

Theoretically, what a human can do and what he can learn to do are part of a single problem. A task which is easy to do often means that it is easy to learn. For example, a task which presents immediate knowledge of results tends (other things being equal) to be more readily learned as well as easier to perform reliably at a high accuracy level Practically, the differentiation is made between phases of activity called "training" and phases of activity called "operational performance."

In order to design equipment efficient for training purposes it is therefore necessary to be familiar with those processes by which human beings learn, and with those conditions generally favorable to learning. Unfortunately for the designer's art, those properties and conditions cannot now be stated in quantitative form. Design must therefore be guided more by principles about the learning process than quantitative prescription.

For this reason the text in this report must be somewhat more discursive than handbooks and guides that deal with "operational performance", a subject matter in human behavior less complex and more readily controlled than "training." That is, the behavior possibilities in learning to operate are clearly more numerous than those in operating the device. Because of this lack of hard-boiled prescriptions in training, it is often necessary to solve problems through awareness of variables and processes. The first chapter of this report represents a minimum of terms and ideas for maximum interpretation of the training process.

This first chapter, like the rest of the report, is a digest and summary of more thorough treatments of training and the design of training devices. The principal reference documents are the following:

Miller, Robert B. A Method for Determining Human Engineering Design Requirements for Training Equipment. WADC Technical Report 53-135, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base Ohio, 1953.

Handbook on Training and Training Equipment Design, WADC Technical Report 53-136, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

A Method for Man-Machine Task Analysis. WADC Technical Report 53-137, Wright Air Development Center Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Human Engineering Design Schedule for Training Equipment. WADC Technical Report 53-138, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Swain, Alan D. Guide for the Design and Evaluation of the Instructor's Station in Training Equipment. WADC Technical Report 54-564, American Institute for Research, Pittsburgh, Pennsylvania, 1954.

Many persons have come to identify "training device" with "simulator." But this report deals with training devices of which "simulators" are only one type or class. Treatment is also given to materials ranging through demonstration charts, mock-ups, and synthetic training devices which are less than the extreme of the engineer's art.

Important as it is to be able to decide what should go into a simulator, it is equally important to decide whether a simulator is necessary, and why a simpler device would not be just as effective from a training standpoint.

In this report, therefore, the term "training device" will be used in the most general way to include any fabricated object, ranging from wall chart to simulator, used for a training program. This usage vastly simplifies the discussion.

This report omits discussion of one important dilemma which the designer of training equipment frequently must face. This is the problem of acceptability by the using agency where there may be pre-existing attitudes contrary to the designer's conviction of what is appropriate. The customer may often have excellent reasons for his attitudes and even for his prejudices. But a policy of "the customer is always right," even when it is against the customer's best interest, sets up a vicious circle which can be broken only when all parties can cooperate on a common basis of information. It is hoped that some of the principles in various of the human engineering guides can help establish such a basis for cooperation.

It would be unreasonable to expect a designer of equipment to require no more than a report such as this in order to design successful training devices. Not only a great deal of specialized engineering know-how but of psychological know-how must be brought to bear in the invention of training equipment which is to be both efficient and economical. It is a major purpose of this report, however, to facilitate team work involving engineering knowledge and skill and that body of knowledge and skill which deals with human behavior as modifiable by training and experience.

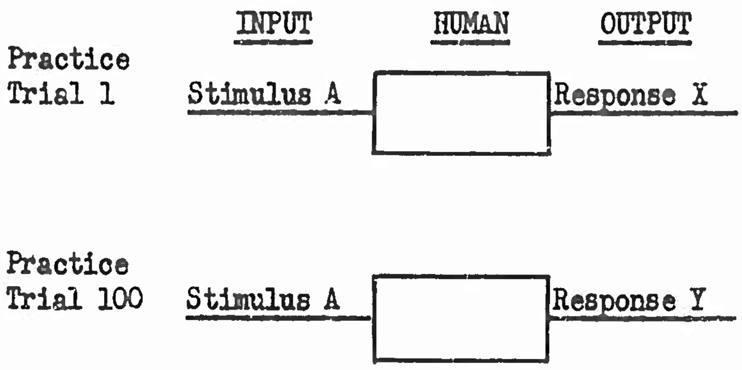
CHAPTER I. SOME PRINCIPAL CONCEPTS IN LEARNING AND TRANSFER OF TRAINING

WE WILL HAVE TO BEGIN WITH SOME OVERSIMPLIFICATIONS! Human learning deals with such a complex of behavior variables, that even to define learning is to enter controversial grounds. So let us start with a somewhat simplified definition and bear in mind that this definition will include most of the other processes identified and defined in the rest of this chapter.

Definition

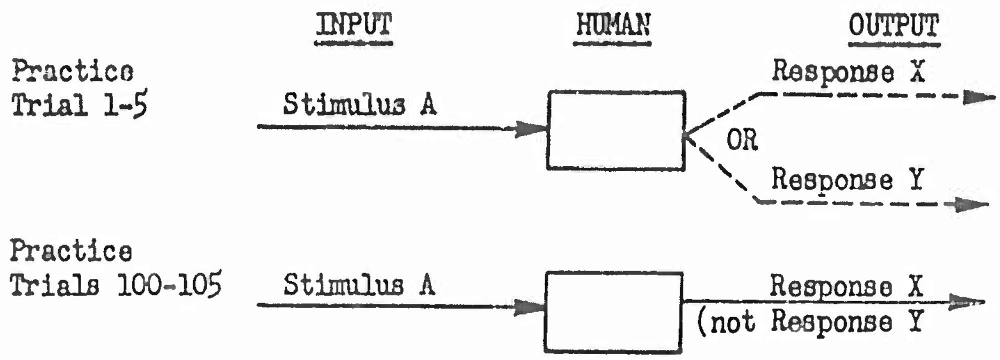
Learning is the process whereby new or different responses come to be made to given stimuli as a function of practice. In practical situations we can identify the effects of learning when we know "what the person is trying to do."

> This definition may be roughly translated as follows: Learning is equivalent to the process of reprogramming the human computer mechanism so that a given sensory input A which has produced output response X now produces response Y. The term "different" in both sentences above should include: "making more reliable a previous response output, such as X, to the given stimulus input."



Response Differentiation

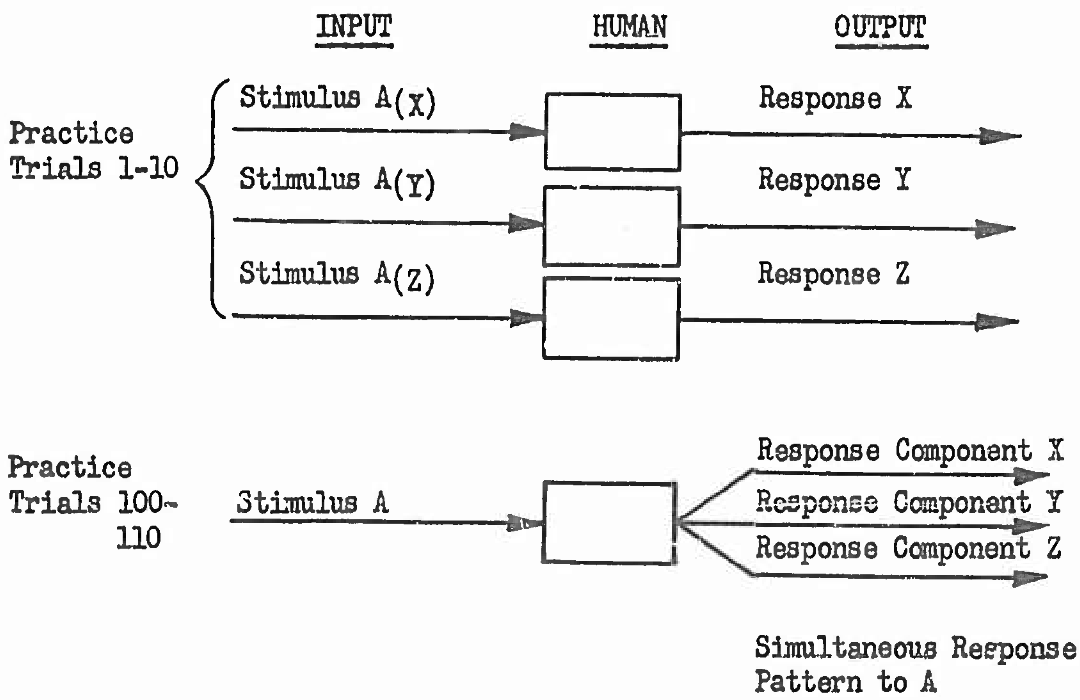
This first general model is an oversimplification because practice may develop capacities or mechanisms for response output. Example: Learning to make to a signal rapid trigger responses with the third finger rather than with either the third or fourth finger. This idea, which we call Response Differentiation, can be shown as follows:



RESPONSE DIFFERENTIATION

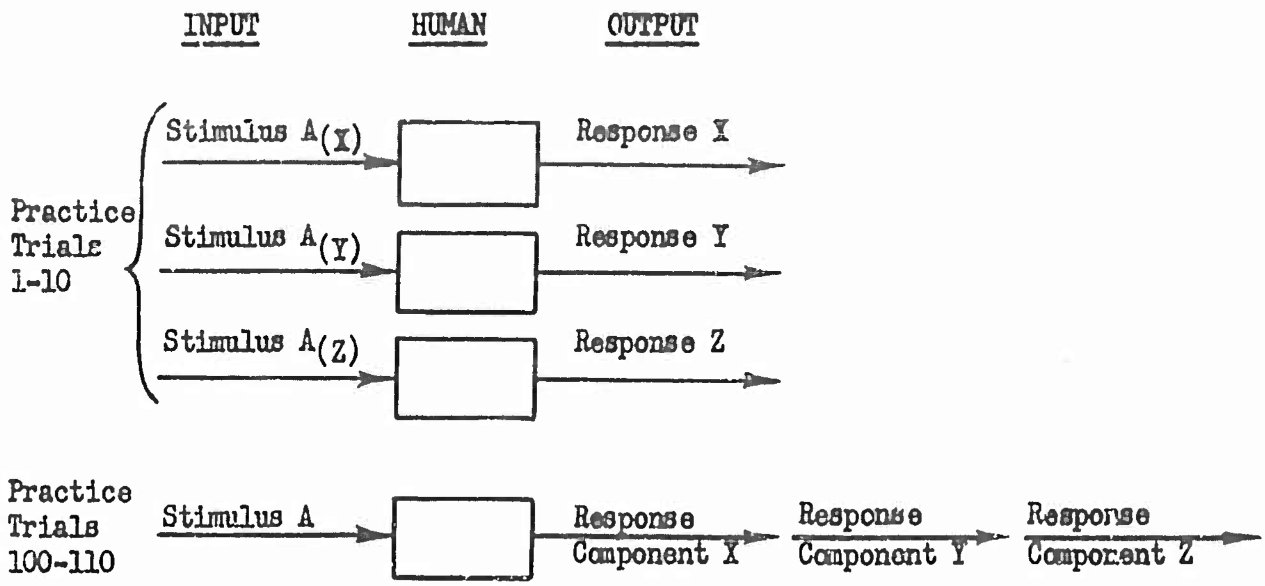
Response Patterning

But the learning process can also result in putting responses together into patterns occurring either at the same time or occurring as a temporal series. These two types of patterning, which are shown in the following diagrams, are called Response Coordination and Response Serialization.



RESPONSE COORDINATION
(Simultaneous Response Patterning)

Example: Learning to move stick, rudder bar and throttle together in coordinated flight.



RESPONSE SERIALIZATION
(Sequential Response Patterning)

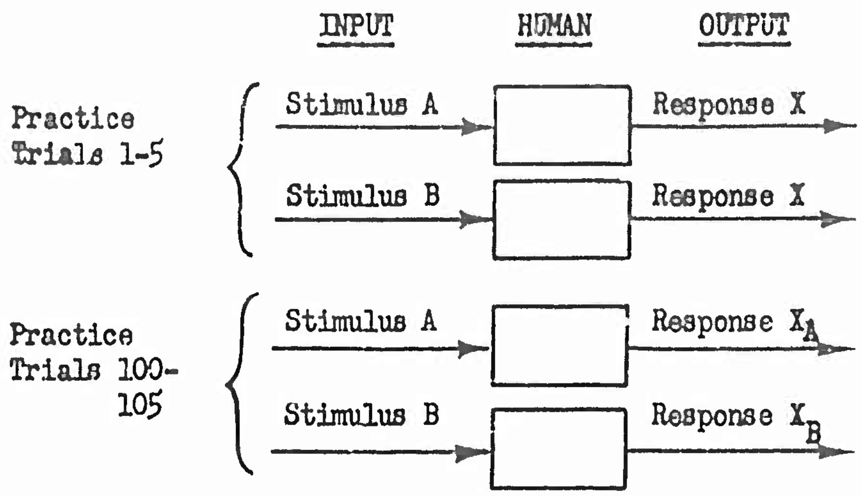
Example: Recall of a memorized procedure; actual performance of a well-practiced starting procedure.

Actually, of course, changes in the "computer mechanism" accompany changes in <u>response patterning</u>, and may be principally responsible for eliciting the response pattern when it becomes a part of the response repertory of the trainee.

(The reader is again reminded that because of the complexity of the interactions within the human mechanism in action, diagrammatic models should always be regarded as scientific fictions.)

Stimulus Differentiation

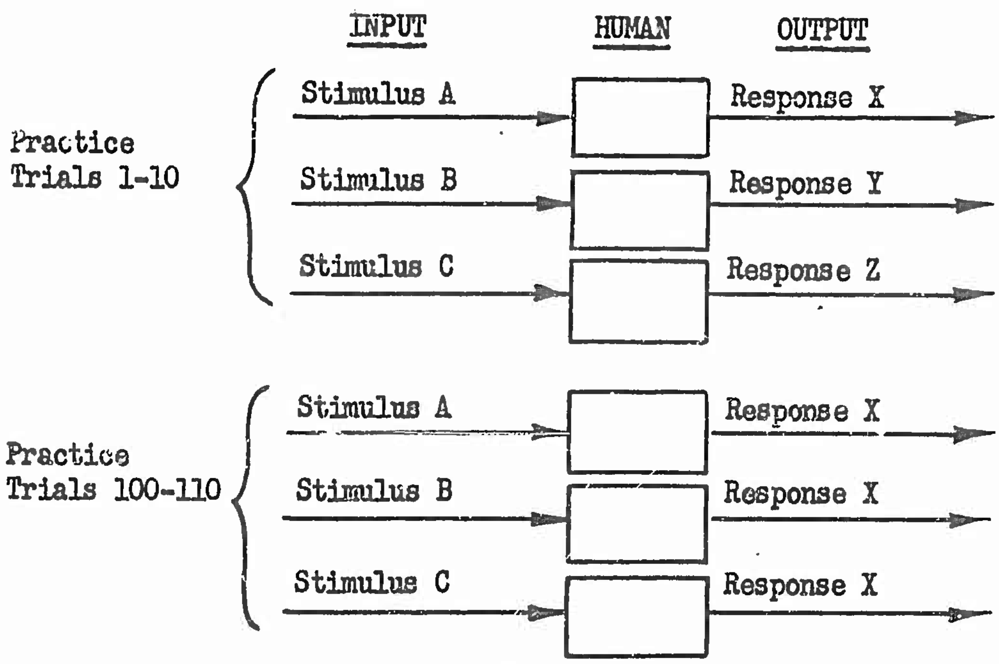
Let us now turn to the input portion of the system. Effects of learning processes may show up as systematic differences in the decoding or encoding of messages presented as inputs. Thus:



Let us call this process STIMULUS DIFFERENTIATION: differential responses are learned to different stimuli to which similar responses were made earlier.

Example: Learning to distinguish a MIG-15 from an F-86E Sabre-jet in the air.

Stimulus Generalization



STIMULUS GENERALIZATION

Let us call this process STIMULUS GENERALIZATION: similar responses are performed to a variety of stimuli which are physically dissimilar.

> Example: Interpreting code messages in the same way irrespective of the pitch of the carrying tone.

Stimulus generalization as a process has its effect in "transfer of training." The validity (success) of a training program depends on the generalization or transfer of responses from the synthetic situation (or synthetic stimuli) to the operational situation (stimuli).

Stimulus generalization may also come about through the learning process. For example, a pilot who reads altitude information from the conventional three-needle altimeter can learn to get equivalent information from a counter-single-needle-type altimeter. To this pilot, after sufficient practice, both instruments are functionally similar with respect to the "altitude response" he makes.

Much of the discussion in later chapters will pivot around the conditions which produce transfer of training and transfer of what kind of training or response repertories. But in order to state principles we will first have to define a few more of the required terms.

Stimulus Patterning

Practical situations invariably require perceptual response to configurations of stimuli in time and space. The car driver responds to a configuration compounded from various instrument readings and complex data about the environment such as road conditions, nearness of other cars, bend in the road ahead, and so forth.

A perceptual response is therefore inevitably a response to patterns of stimulus inputs. A variety of patterns of stimulus inputs may become, through training, functionally equivalent in producing some one response or response group. They may become equivalent by virtue of pattern in space or time or both. In training, an example is the learning of a set of verbal procedures to a photograph of equipment. The trainee does not mistake the photograph for the real objects depicted. Nevertheless, he may transfer (generalize) his verbal procedures quite substantially to the work situation filled with the actual objects in the photograph.

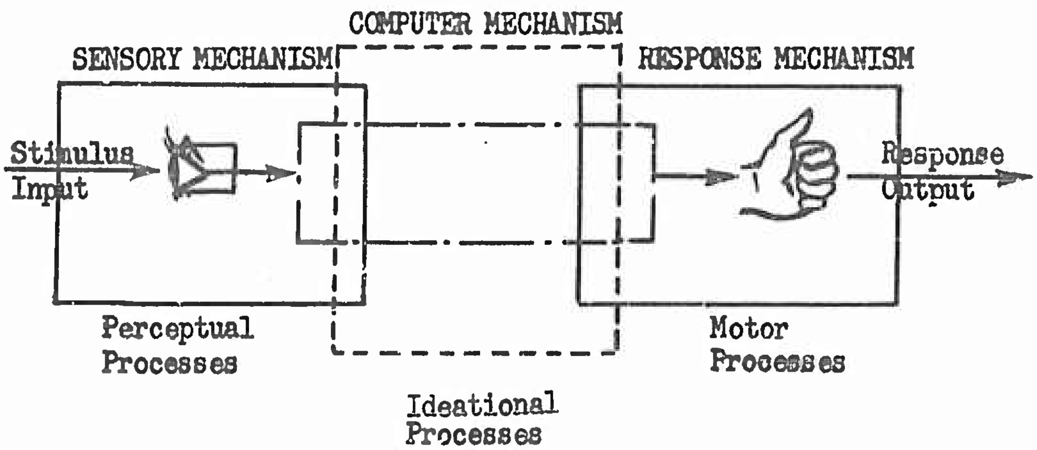
We are also able to recognize a tune played in one key when it is played in another key; a telegraphic message when delivered through the ear by headphones or through the eye by blinkers.

When there is a demand for transfer of training to superficially different situations, some modes of training which emphasize response to patterns of cues will be more effective than others which emphasize specific response to specific cues. Training which directs response to the total configuration of the work environment will therefore enable the trainee to cope with wider varieties of work situation, including transfer from synthetic to actual work environments.

Through practice, certain responses can become at least partial stimuli which trigger off others in response series or groups. When such response sequences are active, they become part of the total stimulus context to which the human responds; this associative response context also helps us understand how human beings can resist irrelevant stimulus inputs during an ongoing task activity. Associative response context also helps account for a pilot being able to have one set of habits appropriate to flying one type airplane and another set of habits appropriate to flying another type airplane, even though the display and control configurations may be quite different. Similarly person can know and speak several quite different languages without one interfering with another.

PERCEPTUAL, IDEATIONAL AND MOTOR PROCESSES

It is sometimes helpful (although sometimes misleading) to differentiate segments of the learning process into PERCEPTUAL processes, IDEATIONAL or SYMBOLIC processes and MOTOR processes.



This distinction is important because under some conditions the ideational processes (thinking, reasoning) may become by-passed by virtue of the learning process. Such by-passing has important implications for learning and for capacities for performance.[1]

Ideational processes include encoding, i.e. transforming an environmental stimulus into a symbolic stimulus; associative symbolic stimulus-response pat-

1. The diagrams on p. 12 show symbolic and non-symbolic channels.

terns stored in memory (as in self-instructions); and the conversion of symbolic responses into response output. Ideational processes also may include "anticipatory" systems and purposive or motive-incentive processes.

HOW DO WE GET THE TRAINEE TO MAKE NEW RESPONSES?

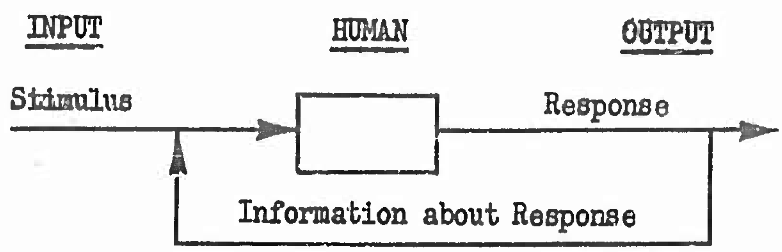
In order for a new response to be learned to a stimulus A, it must be practiced to stimulus A. But how do we get a new response to occur in the first place?

In humans, an important mechanism is that of symbolic stimulus-response. For example, a red light appears on a panel. The trainee's hand remains idle on the control panel. The instructor tells him that when the light appears he must press switch X. On the next trial when the light appears to the trainee it combines with the symbolic stimulus-response (the instructions) and the trainee presses switch X. He has made a new response.

Now let us go on to the situation in which the trainee uses the consequences of his response to improve his response output.

Informative Feedback

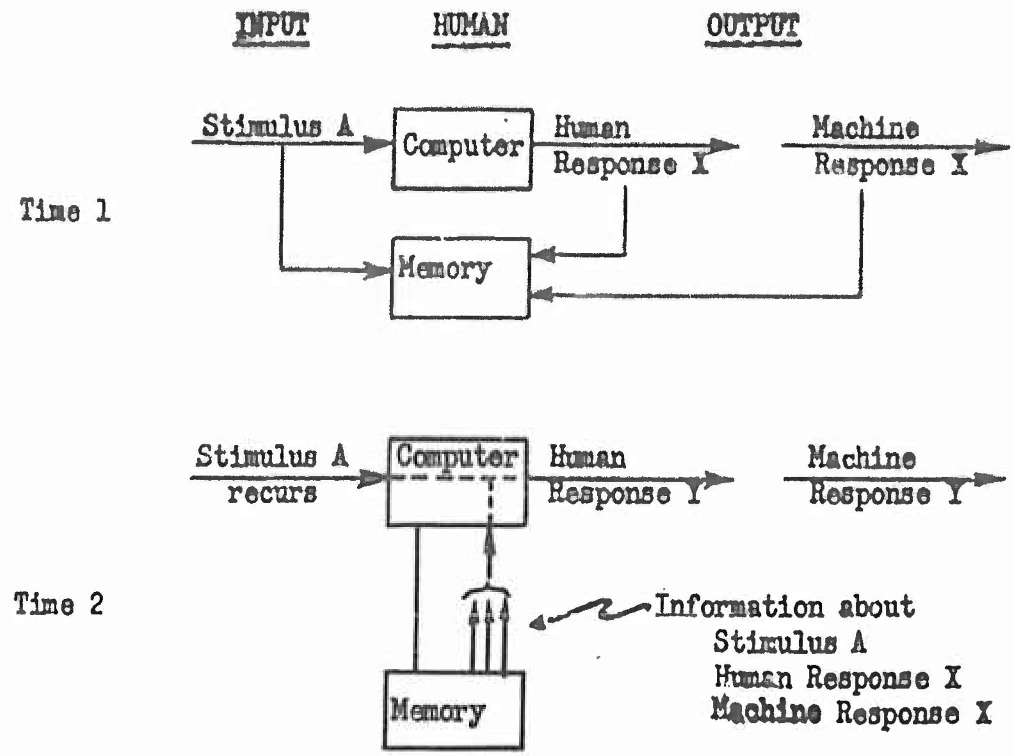
The following diagram contains the elements of a feedback system.



FEEDBACK CHANNELS

There are two major types of informative feedback. The distinction is based not necessarily on any characteristic of the signal itself, but in the way it is used by the trainee.

Learning feedback: Let us presume voluntary or "ideationally" guided behavior. A feedback system presents the trainee with his response output compared with what that output should have been.



LEARNING FEEDBACK
(Feedback acting in time)

In this case, the error feedback results in a change in the computer (or as stored information) so that when stimulus A recurs on a later date, a somewhat different signal will be issued from the computer to the response mechanism. That is, in effect, reprogramming the computer. In this way a man learns to aim a gun better on the tenth day of practice than on the first if he sees the size and direction of his misses.

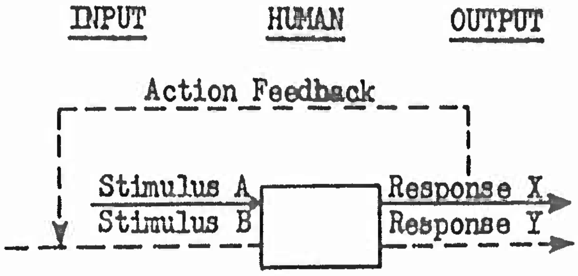
Let us call feedback which acts in this way "learning feedback." Another term for this activity is knowledge of results. But usage also gives another meaning to "knowledge of results" as our next example will show.

The effects of learning feedback are not revealed until another occasion on which INPUT A occurs as such. On this occasion, INPUT A produces a response compounded of the response tendency and the "correction factor" introduced into the computer by the learning feedback. The resultant is response Y which, we hope, has less error in it than did the former response X.

(It is as if the mechanism said: "When Stimulus A occured I should have made Response Y instead of Response X and the next time Stimulus A occurs I will respond with Y.")

It follows that the more efficiently the learning feedback informs the trainee about his response, the more readily he can learn. He should be informed only about what he can control. We conclude that for efficiency in training, learning feedback should not be contaminated by machine variable error. In this respect, as in others, the synthetic training situation may be more efficient than the operational training situation.

Action feedback: Consider a tracking task such as pointing a gun at a moving target. The difference (error) between momentary point of aim and target position is a signal fed back to the operator who uses this information as a stimulus for succeeding momentary corrective adjustments. Because these adjustments direct action to the error signal by utilizing present programs in the human computer, let us call this information "action feedback."



Solid line = Time 1
Dashed line = Time 2

ACTION FEEDBACK

(Here it is as if the computer said: "Response X must now be changed into Response Y in order to reduce the error now presented.")

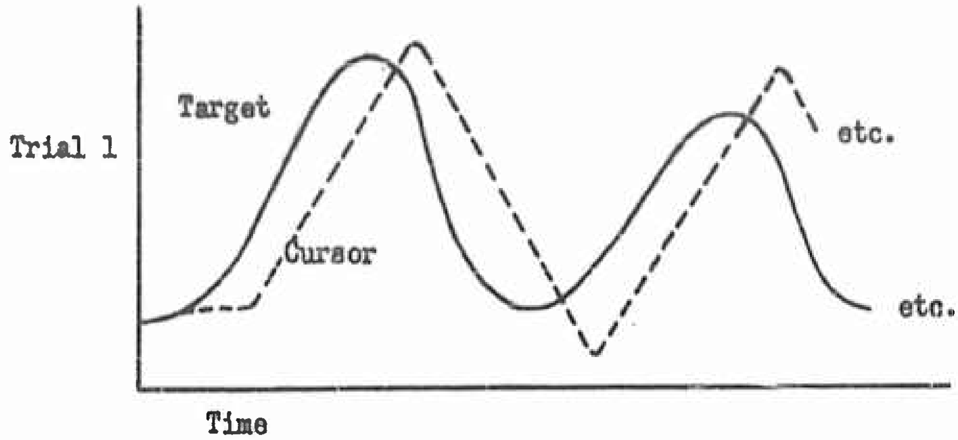
Note that action feedback does not change the characteristic of the computer (by definition) but learning feedback (by definition) does tend to change the characteristic of the human computer. The same external channel of error information may carry both action feedback and learning feedback. Whether the feedback signal acts in one capacity or the other, or both, is in part due to the "set," "intent" or motivation of the trainee operator.

Response to available feedback is always selective at the perceptual, ideational and motor levels. Effective training guides the selective tendencies of the trainee, according to his momentary capacity for handling pattern of learning feedback plus action feedback.

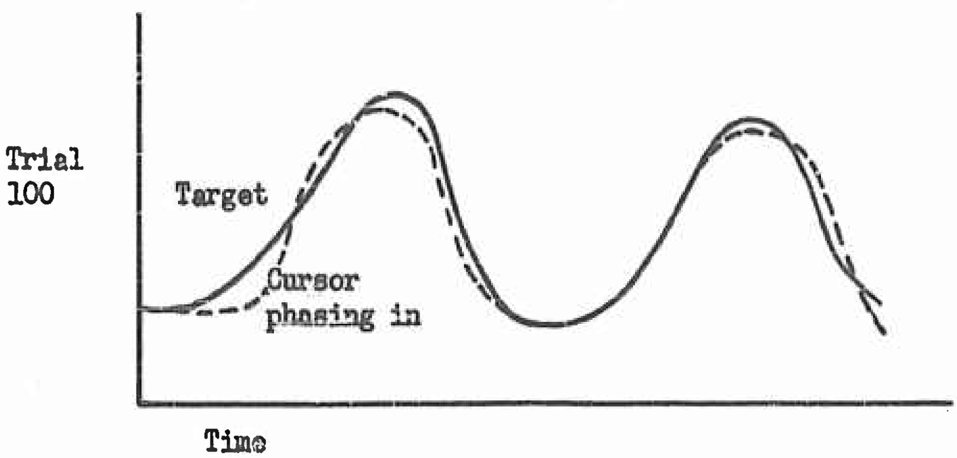
Many persons, including specialists, use the term "knowledge of results" to include either or both learning feedback and action feedback. In fact, the distinction between action and learning feedback has rarely been recognized. Because of the important implications to training of the difference between these two terms, however, we will use them in this report.

Changing Response Through Anticipation

Let us assume the path of a target has a given characteristic such as that of a sine (regular) wave. On trial 1 the operator will be one reaction-time behind the target.



Notice the lag of the cursor response, and the resulting over-travel. With continued practice he will learn to anticipate the course of a target upon identifying that target and getting into phase with it.

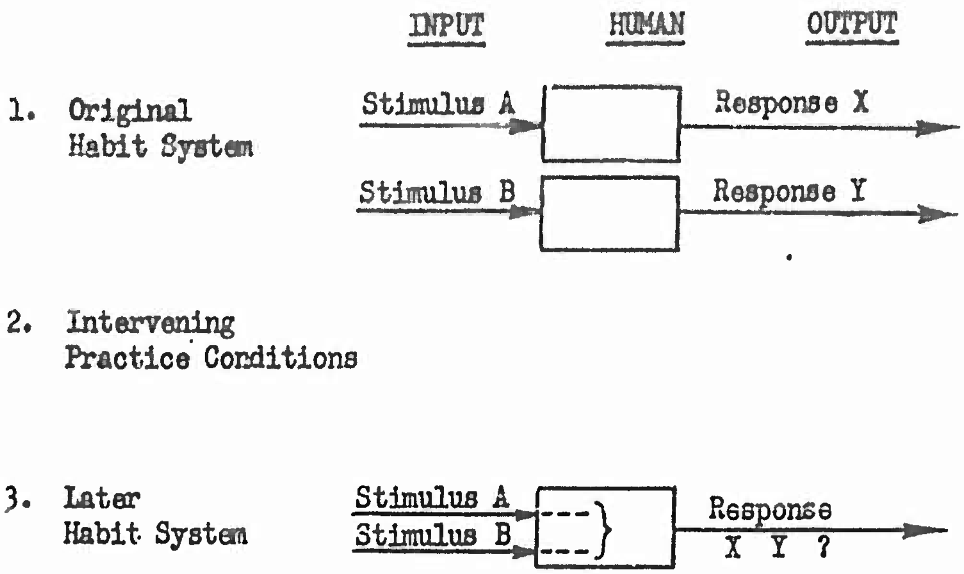


Now notice that after the initial latent period, the cursor catches up to the target and instead of merely following it, keeps up with it. It is convenient to think of this performance as showing anticipation of what the target is going to do next. The human computer which guides the cursor (which may be the human hand itself) has acquired the same program as that of the target's generator, plus a phasing-in mechanism. The phasing-in mechanism keeps the cursor track from remaining one reaction time behind the target track.

Note that learning may reach the point at which no more than the target signal at time 0 (zero) need be shown. From this starting-signal, the human computer may trace out the proper space-time path without further data from the target during the mission. This is the analogy in tracking behavior of the conditioned response.

Changing Response Through Stimulus Combinations

Response to a given stimulus may change when that stimulus becomes a component in new patterns of stimulation. Thus the contours of a battleship at sea may become unrecognizable when it is camouflaged. (Later we shall see that there is not a one-to-one relationship between response to a physical stimulus in one context and to that physical stimulus in another context of events.)



CHANGING RESPONSE THROUGH STIMULUS COMBINATIONS

The brace in the computer symbolizes a combining activity.

Speaking in general terms, stimulus contexts include one or more of the following factors:

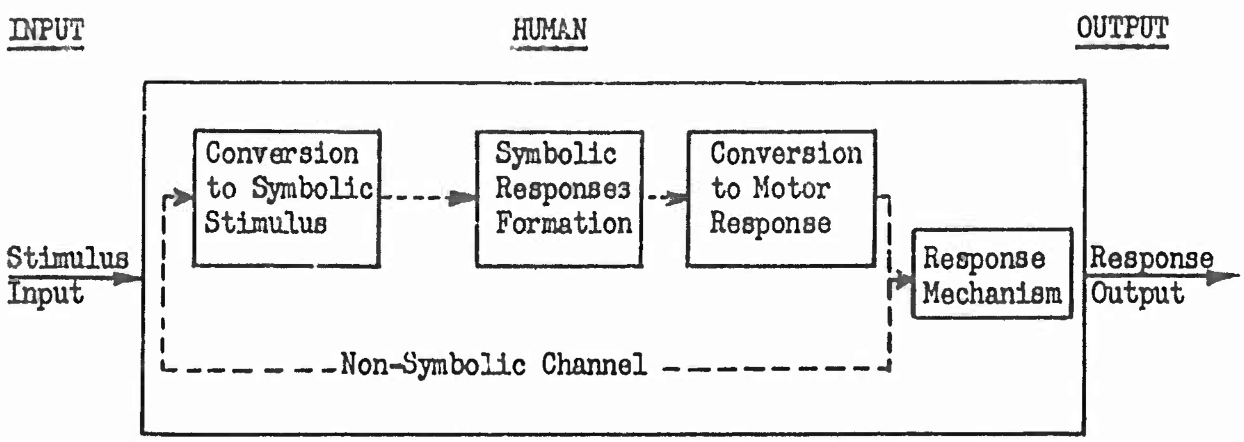
What other physical stimuli are present at the same time
What physical stimuli preceded the stimulus
The prevailing "motivation" of the trainee
"attitude"
"set to respond"
etc.

The terms motivation, attitude, set to respond, put huge burdens on keeping our model simple. Let us for the time being recognize their importance to learning processes without trying to get them into our diagram.

Incidentally, practice to suitable combinations of stimulus A and B may lead to <u>both</u> responses X and Y being made to <u>either</u> stimulus A or B.

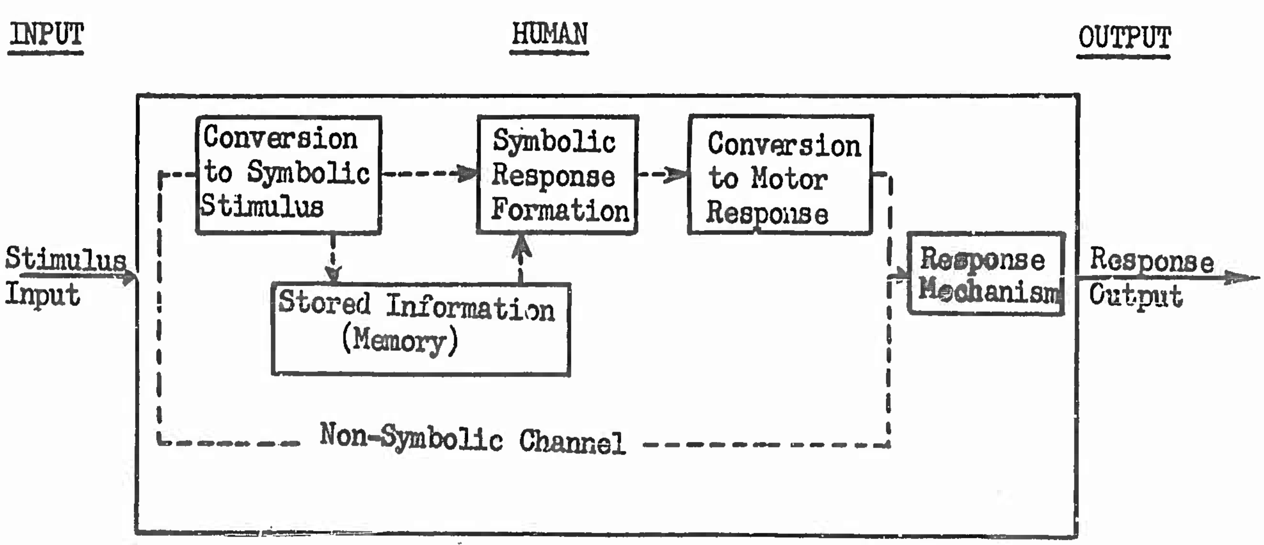
Changing Response Through Symbolic-Ideational Activity

Training usually refers to highly complex behaviors acquired more or less through voluntary intent of the learner. We must therefore include as perhaps the most significant determiners of new responses to environmental inputs, the capacity for symbolic stimulus-response activity. Thus the driver may think or say to himself: "This map shows a short-cut; therefore, when I come to the next corner (new symbolic stimulus) I will turn right (new symbolic response) instead of turning left (old symbolic response)."



CHANGING RESPONSE THROUGH SYMBOLIC IDEATIONAL ACTIVITY

Notice, however, that the driver was using stored information when he recalled the short-cut shown on the map. Let us add this as another feature to our diagram:



SYMBOLIC BEHAVIOR UTILIZING STORED INFORMATION

Symbolizing processes imply decoding and encoding capacities of the central mechanism. That is, in order for symbolic activity to occur, there must be symbolic representations of stimulus inputs and output responses compatible with each other and with stored information. This matter of code compatibility is an important area in the study of human behavior.

Note, however, that we have vastly expanded the learning-capacities of the mechanism by introducing symbolic behavior!

The following kinds of "information" can be and are symbolized in the human computer system:

Stimulus objects, stimulus relations, stimulus classes
Responses and "sets to respond"
Response feedback
Motivations, incentives and goal conditions

Symbolic processes or coding systems include words, images and conceptual processes, few of which can be precisely correlated with objective items or sequences. For our purposes, it is more or less sufficient to know how to control the external conditions under which these processes can be induced so as to affect learning and performance.

It will be convenient to refer to these symbolizing processes which occur inside the human "black box" as mediating stimulus-response systems or activities. They "mediate" stimuli from the environment and responses performed on the environment. Such processes have payoff significance in problem-solving activities, in the giving of self-instructions, and in the making of decisions. All three of these activities are probably closely inter-related.

Ideational stimulus-response systems have an important role in transfer of training in that they can make superficially different stimuli similar. We can say or think "One dollar" whether we see or think of a hundred pennies, a dollar bill or the figures $1.00 printed on a check. Through suitable use of ideational capacities we can speed up the learning of complex motor responses, and amplify the range of stimuli to which training can be generalized.

Changing Response Through Habituation, Sensory Adaptation, Fatigue

Within limits, the magnitude of response to a constant value continuing stimulus input tends to diminish. We plunge into water which seems cold at first but after ten minutes the water's temperature seems neutral, unless it is below certain limits. Noises on a telephone, which at first may be disturbing to a verbal message, become less noticeable after a few minutes conversation. The more constant and less variable the background portion of the stimulus, the more rapidly it ceases to distract -- that is to elicit disturbing or other responses.

When this phenomenon occurs within one session of activity it is called "sensory adaptation" or "negative adaptation." When it happens from one session of activity to another it is called "habituation."

Some writers have related sensory adaptation and habituation to sensory fatigue, but we need not be concerned with the problems raised by this issue.

Two important conclusions can be recognized from these phenomena:

1. An input will tend to act as a stimulus (that is, produce response) when it is a change in some previously existing state of inputs. Its strength as a stimulus will be related to its rate, as well as absolute magnitude, of change. The organism is rarely placid to environmental inputs of the moment, however; it contributes to the stimulus conditions through ideational and motivational (purposive) activity.

2. Response outputs are modified through the organic phenomena of sensory adaptation and habituation.

Note to the academic reader: Vexation is caused by the frequent ambiguity of the term "stimulus." Let us agree that an environmental stimulus input be thought of as a stimulus only when it elicits an actual or hypothetical response in the human system. This distinction has substantial bearing on our later distinction between engineering simulation and psychological simulation (see Chapter II, page 2).

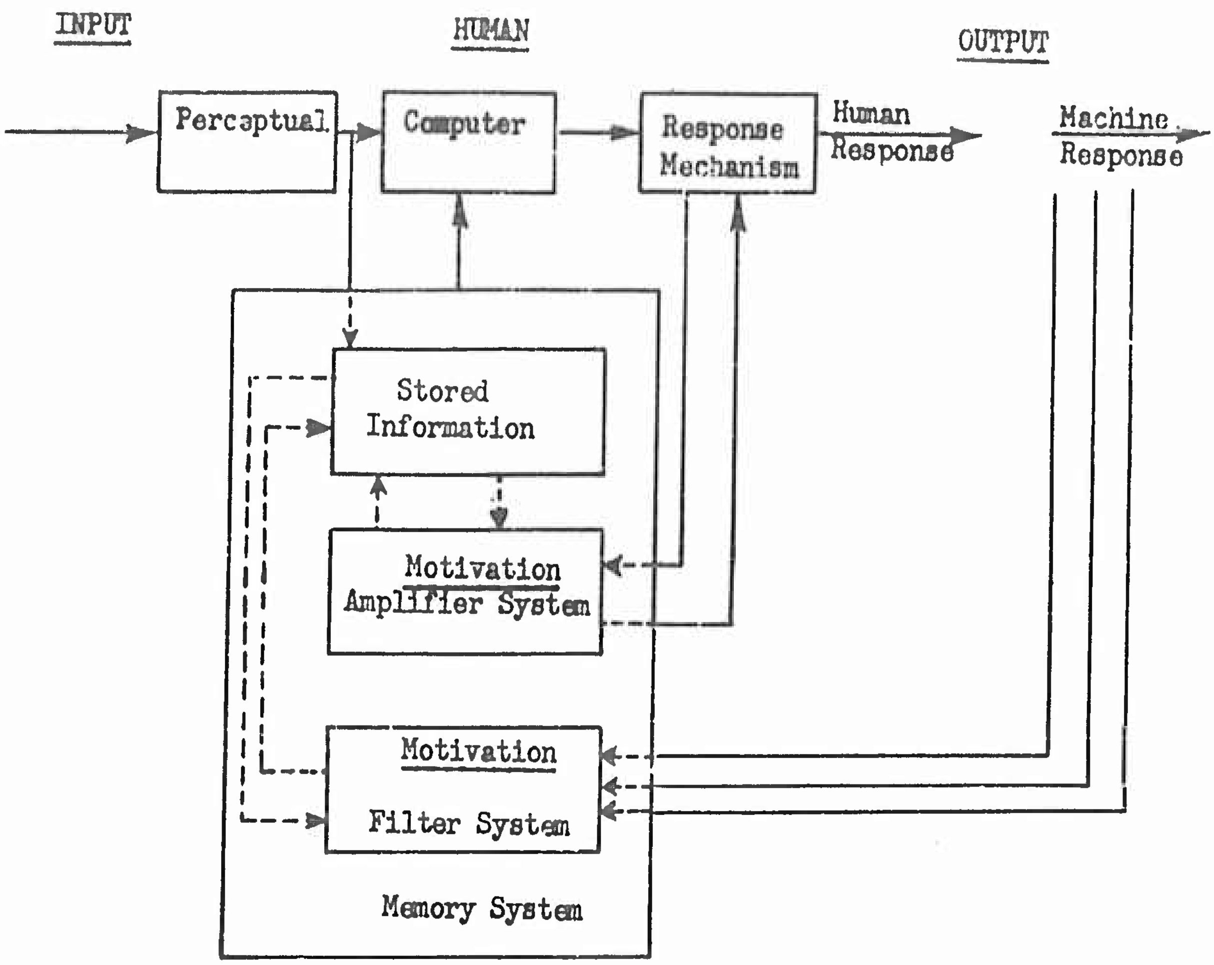
Objectively, fatigue is the reduction of the likelihood of a given response to a given stimulus configuration as a function of the rate, frequency and recency of making that response. This observation seems to hold for ideational as well as motor processes. As a consequence of practice, learning effects tend to be obscured by fatigue effects; and the learning process may, in some respects, interact with the fatigue process. In general, learning effects are more persistent than fatigue effects. Nevertheless, the interaction of the learning and fatigue processes suggests optimal periods of practice versus rest for any given type of task. Research into "massed versus distributed practice" confirms this by showing diminishing returns for time spent, beyond a given point, in continuous practice before a rest interval. Optimal ratios of practice to rest, and times for rest, are related not only to kind of task, but to incentive conditions and stage of learning.

In any event, sensory adaptation, habituation and fatigue can account for changes in response. To the extent that these changes in responses are consistent, they may become part of the total pattern of response.

Motivation

Our treatment of motivation will be necessarily brief and cavalier. Let us presume (often rashly) that the trainee wants to perform the job reliably although actually part of the function of training may be to induce a desire to learn the skills required.

We can think of motivation as performing two main functions in the learning model: an amplifier of response tendencies and a filter of response feedback.



MOTIVATION

Motivation energizes the learning-action system, and energizes it selectively. Motivations may be highly specific, and are learnable. They are identified through incentives. An incentive is some goal (or null) position selected out of a number of possible goals or goal variables.

Example: A pilot trainee is motivated to reduce azimuth error. He does so, but neglects error in elevation and tracking smoothness.

Motivations are also incorporated in attitudes of acceptance or rejection of objects and situations. Gross attitudes of rejection interfere with learning and transfer of training.

SUMMARY

Learning is the process whereby new or different responses are made to given stimuli as a consequence of practice. Practice is defined as making a given response to a given stimulus. Practice may develop new capacities for response output through response differentiation, response coordination, and response serialization. On the stimulus input side, suitable modes of practice develop stimulus differentiations, responses to complex patterns of stimulus inputs, and transfer of responses.

For convenience in the planning of training it is helpful to distinguish between perceptual, ideational (symbolic), and motor processes.

In order to learn a new response, it must be made and made to the appropriate stimulus. Processes by which new responses can be induced to occur include (a) the development of anticipations, (b) stimulus combinations, (c) symbolic activity, (d) sensory adaptation and habituation -- or combinations of these processes.

Essential to improvement in skill, however, is information about the results of the output response. When this feedback is carried over into a recurrence of the original stimulus so as to reduce error on the later trial, the signal is called "learning feedback." When an error signal is used to modify the response in progress it is called "action feedback." Much efficiency in learning depends on the availability (and use by the trainee) of appropriate learning feedback.

Motivation acts as an amplifier to the entire system and a selective filter to feedback information.

TRANSFER OF TRAINING

When a response is made to a stimulus it tends to get learned to that stimulus. When that stimulus recurs, the response will tend, by the degree it has been learned, to recur also. (In one sense, the response is "transferred" from one occurrence of the stimulus to a later occurrence of that stimulus.) But a set of stimulus events is never precisely repeated. It is therefore dangerous to speak of "the" stimulus as if we ever could specify all the stimulating conditions which, at any moment, are associated with a given response. Nevertheless, when responses recur to stimulus events which were similar to the earlier stimulus, we speak of memory or habit.

But we may change the original stimulus in a variety of ways and find in some cases that the responses, in some degree, transfer to the changed stimulus. We will find cases of high transfer of response to apparently very dissimilar situations. In other cases we will find that even rather small changes in stimulus conditions produce little transfer of an earlier response. If we can be specific about which conditions make for greater and which for lesser transfer of response (or training) we can obviously be economical in training. This will be especially the case if the operational conditions involve stimuli very expensive to produce, such as an airplane, guns and aerial targets.

Transfer of training is transfer of responses from one set of stimulus conditions to another set of stimulus conditions. Training devices and classroom studies set up synthetic stimulus situations. We hope that the responses learned to these synthetic situations will: (a) aid in learning operational responses; (b) transfer positively to operational situations; (c) cover operational situations.

An additional note. We have "transfer of training" even when the transferred habits are inappropriate to the new situation. In such cases, the habits may interfere with the learning or execution of the correct response in the new situation. This is usually the problem in transition training where similar sets of stimuli now demand different (and even reversed) response patterns. This "transfer of training" has negative or interference effects. Obviously, training should be directed not only towards transfer of habits to operations, but transfer of appropriate habits and the avoidance of inappropriate habits and attitudes. The transfer of these latter may require unlearning during operations which can be hazardous as well as expensive.

Perceptual Sensitivity And Stimulus Variation

Human receptor channels, like other receivers, have limitations in sensitivity. That is, for any stimulus input, there will be ranges through which physical differences will not be matched with behavioral differences. These ranges of insensitivity will differ for different modes of response.

For example, a person may readily distinguish a white from a yellowish illumination in stepping from one room to another; if however, you ask him to read a passage of prose first in one room and then in the other, no difference in reading may be discovered within the criteria established for reading effectiveness.

Similarly, seasoned pilots may be able to tell us that the feel of the controls in a simulator differs from the feel of the corresponding controls in their aircraft. Their performance of maneuvers in the simulator may, however, reveal no measurable difference of response output within the operational criteria established for that performance. On the other hand, the converse may be true: differences between stimuli which an operator may fail to discriminate at the verbal level may show up in job behavior.

Stimulus validity should therefore be established on the basis of what the operator has to do on the job, rather than irrelevant responses.

Economy and feasibility require that the training device copy the operational equipment only within the range of stimulus inputs which produce, or are likely to produce, a demonstrable change in essential job behaviors. Parameters and formulas are not now, or in the near future likely to be, available for estimating "transfer sensitivity" to stimulus differences. The educated guesses of specialists in human learning will probably be the best basis for decisions.

Transfer And Type Of Task

It has already been suggested that some types of activity transfer to a wider range of stimuli than others. For example, ideational forms of behavior tend to be less "stimulus-bound" to specific environmental cues than most kinds of manual or motor response.

We can also expect differences in transferability among types of motor performance. Let us distinguish between procedural tasks and continuous feedback tasks.

Procedural or discontinuous tasks are tasks in which separate, mainly all-or-none, responses are made to given cues. Following a set of printed (or remembered) instructions in pressing a series of switches to a sequence of signals would be an example. Procedures are often verbally mediated. When they are, they may transfer to widely different stimulus inputs. With high degrees of practice, of course, verbal mediation may tend to drop out and the responses become automatic. When they do, we will get somewhat less generalization to different stimuli.

Every job has a large number of procedural portions, many of which can be learned with relatively crude physical copies or even symbolic representations and mock-ups.

Continuous feedback tasks are also known as tracking tasks. Performance involves a continuously changing response to a continuously changing stimulus input. ("Continuous" refers to the maximum continuity capable of the human operator as a system.) The response is a continuous adjustment by the operator to a changing error signal. The error signal results from the operator's comparison of the desired output with the changing output signal which is fed back to him.

In general, transfer of training in tracking tasks tends to be more restricted than it is in procedural tasks, especially if time changes are involved. That is, the operator learns sets of anticipations of signal inputs, and when these anticipations do not conform to the sequences and patterns of cues in the new situation, the old responses are inadequate.

This topic is given expanded treatment in Chapter III, Stage of Learning and Physical Simulation, p. 31.

The statements in this chapter are intended to present an introductory overview to the concepts in the following chapters which will apply these definitions to problems more directly connected with equipment design.

CHAPTER II. PROBLEMS OF PHYSICAL SIMULATION

INTRODUCTION

Training consists of the acquisition of skill in using equipment in operational environments. Let us call any set of environmental conditions a "program."

A simple example may clarify the meaning of the terms. We wish to train a person to drive a car. This statement may imply programs but it does not specify them. Driving a car on the open road; in dense city traffic; two-lane, truck-cluttered roads; icy roads; night illumination -- all these are program variables in driving.

The problem of simulation must take into account the representation of programs as well as the representation of the equipment and its functioning to the trainee.

PSYCHOLOGICAL SIMULATION VERSUS ENGINEERING SIMULATION

Simulation is not all or none; it is a matter of degree. Perfect simulation consists of the job itself performed on operational equipment in the context of all its actual programs. The fact that a situation is synthetic in itself is less than complete simulation. Items, functions, and programs are selected for copying, and each for copying to varying degrees of physical reproduction.

We should therefore not speak of physical simulation as if it were an object which must be either present or absent. Even in physical terms, simulation is a matter of degree.

The Training Problem

But the training problem is not a matter of physical copying of equipment and its interactions with physical replicas of programs. Let us give the name "engineering simulation" to the copying of some physical model and its physical properties.

The training problem is to provide stimuli so that responses learned to them will transfer from training to operations with little or no loss. When responses learned in training transfer into appropriate action in operations, let us think of the relation of the synthetic to the real conditions as "psychological simulation."

Psychological simulation may be far removed from physical realism. Take an extreme example. An instructor tells a trainee in a bare classroom that when he enters an airplane cockpit he should immediately slam the cockpit door forcefully. The trainee goes out to the aircraft, enters it, and slams the door forcefully. The classroom situation has, in terms of the job outcome, (in this instance) psychologically simulated the operational situation.

In this case, the simulation was effected by symbols--words in sentences presented to the trainee who "practiced" the response of slamming the door symbolically to a symbolic stimulus.

The point here is not "Can you train such a response in this way?" The point is, "To the extent that there is transfer of response so that the job is performed correctly, we have psychological simulation."

Interrelationship Of Transfer, Economy, And Engineering Simulation

Failure to distinguish between psychological and engineering simulation may produce costly excesses. The engineer is charged to "build a simulator." At once he undertakes to synthesize in hardware all the physical apparatus, and perhaps one or two arbitrarily chosen "programs." His limits are defined only by budget and the state of the engineering art. There are kinds of task and degrees of learning which may profit from high degrees of physical fidelity in many features of the task environment. Other tasks, or degrees of skill, may be learned and transfer quite adequately from synthetic trainers having relatively little physical or functional realism.

At least from the standpoint of economy, the development of training devices should rest on psychological simulation rather than engineering simulation. Therefore to the extent that engineering simulation is a matter of selection and of degree, the selection of variables should be based on psychological considerations as to what will maximize validity of training.

With respect to the psychological simulation of tasks we will be concerned with two main problems. One of these is the extent to which the training includes what is necessary to include. The other problem is what can be excluded as irrelevant to the training problem. Cutting across both of these considerations is the degree to which engineering variables in the training situation need to duplicate the operational situation for practical amounts of transfer to obtain. Although the interrelationship of these three considerations has been recognized, the independence of them has not generally been made explicit.

Once we recognize that there are degrees of both engineering simulation and degrees of psychological simulation, we must realize that practical decisions about the specifications for training equipment must rest on economic and training objective compromises. As engineering simulation increases, the equipment tolerances grow tighter and the equipment becomes more expensive to build and maintain.

At least up to a point, there are increments of training value (depending on the kind and level of skill which is being trained) with increased engineering simulation. But the gains in skill may be uneconomical from the standpoint of the dollars and cents involved in building and/or maintaining the training device.

To take an extreme example, we should not spend a million dollars to build a training device when the task can be taught just as well on the operational device to the ten thousand trainees we need for a dollar apiece.

The figure below is an oversimplified demonstration of the relationships between degree of engineering simulation, cost of such simulation, and the amount of transfer of training value to be derived from increased engineering simulation. The figure may be interpreted roughly as follows. The line marked "cost" shows that as degree of engineering simulation increases, costs go up at an increasing rate. This increase in cost is particularly true when not only the mean of some variable on the operational equipment is reproduced, but when this mean is reproduced with increasingly small operating tolerances in the training device.

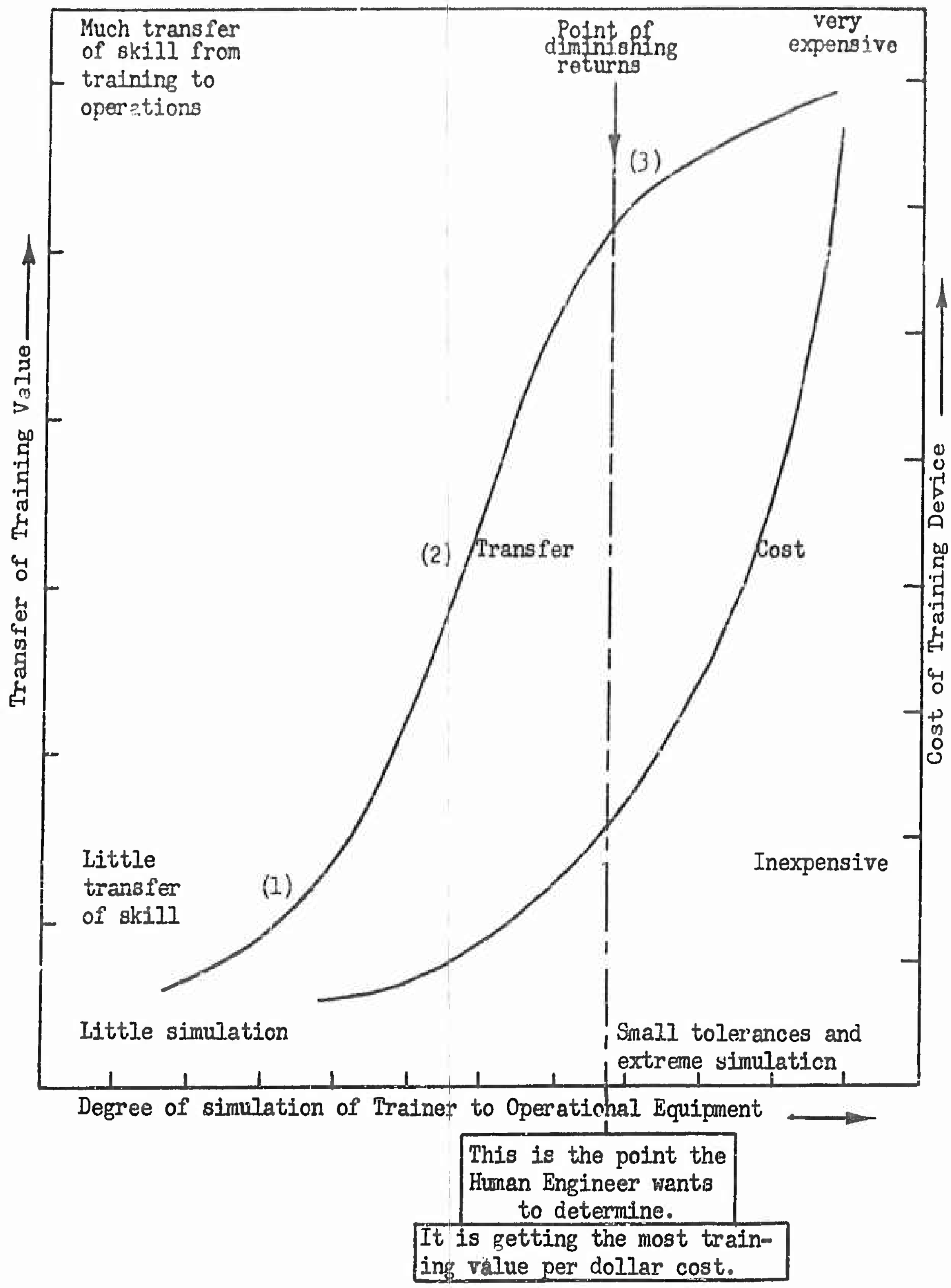
But physical realism is not only a matter of degree with respect to a variable, but also in number and kind of variables represented. That is, more and more characteristics of the operational situation may be put into the trainer, and each of these added characteristics may increase cost disproportionately through multiple interacting linkages.

The relationship of cost to degree and kind of simulation can be rather readily determined, although in actual situations these variables may not lend themselves to as simple a presentation as is made in the drawing below.

The line marked "transfer" in the figure is a hypothetical relationship between degree of engineering simulation (of one or more variables in

Schematic Relationship between Degree of Engineering Simulation, Cost, and Transfer of Training Value.

(Assuming motivation to be constant and high.)



the operational task) and the transfer value which may arise. At very low degrees of engineering simulation [(1) on the diagram] we may expect relatively small gains in transfer value with given increments in engineering simulation. This statement is interpreted as follows: With low degrees of engineering simulation the trainee will be making verbal or other mediations of both display and control components of the task, and will be transferring to the operational task little more than the identification of controls and display features, nomenclature, and perhaps skills in gross procedures limited to direction of movement of display items and control items.[1] He may also be acquiring some concepts of the action of the equipment in some context. But since this stage of learning will have a high verbal content to mediate generalization, increases in degree of engineering simulation will tend to result in little or no increase in transfer value for this stage of learning.

(2) However, as learning is carried to higher degrees, especially in tasks requiring perceptual-motor coordinations and rapid sequences of accurate perceptions and movements, increments in engineering simulation have increasingly higher transfer value, assuming the training on the training device is carried only to a degree optimum for that device. But degrees of engineering simulation can be reached where dividends by way of transfer of training grow less, that is, diminishing returns set in. It is in this region that production costs may mount disproportionately.

(3) Finally, we can postulate degrees of simulation beyond which no appreciable gains in transfer can be found; that is, where human variability and limitations of capacity to discriminate situation one from situation two are greater than variations between operational and training equipment, or are greater than the "reliability" of the training equipment during its operation.

Unfortunately, we do not know the parameters of this transfer curve. Except for a few scattered reports about one or two task variables, there is available little information from which an actual transfer curve could be drawn. Perhaps one of the principal difficulties has been that the various dimensions of the problem have not been made explicit. An attempt will be made in the following pages to do so. When the various premises of the problem have been established, it is to be hoped that some conclusions of a practical, even though rule-of-thumb, nature can be drawn until more experimental evidence becomes available.

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1. Of course, if the above is all that the training task need teach, then transfer value can be high for these procedural skills, and with a low degree of engineering simulation.

SIMULATION AND THE SAMPLING PROBLEM

Let us take a different tack. Let us ask, "What shall we select as our operational model to simulate engineeringwise?" What mean values and tolerances shall be used in the construction of the 10 or 100 copies of the training device? Every B-36 has somewhat different characteristics than every other B-36. Which B-36 should we copy?

Sources of variability will be discussed under two main divisions. One of these divisions will discuss the variability from moment-to-moment of a given unit of equipment. The other sub-topic will be the variability between different units or samples of the same equipment.

The practical outcome to the manufacturer of this discussion on variability will be guides as to tolerances to be built into training equipment.

Within-Unit Variation

A given aircraft will function somewhat differently from day to day. The greater the extent to which an attempt is made to standardize the conditions of its operation, the less variable will its performance be. But in practical situations, standardization is only a matter of degree. To cite only a few sources of variability, even though it were subjected to exactly the same situational conditions, there are: variations in maintenance, age of the equipment, fuel, differential types of wear on components due to special history of the equipment, fuel load, loading of the equipment, stage of warming up, and so on.

So we can expect that to some degree, a person operating a given piece of equipment will have a task somewhat different each time he operates it.

Insofar as the operator is concerned, these physical differences may not result in any "practical" difference to him in the performance of his task requirements. Thus he may not be able to report any difference between equipment N as it operates today and as it operated yesterday. Nor will his task necessarily be materially different in performance. Obviously, there will be differences whenever the error components of a system are changed, but these differences may not be measurable, or they may not fall outside the tolerance criteria established for effective performance of the man-machine task. We may thus speak of the operator as being insensitive to such machine differences. It is not important at this point whether or not the operator can or cannot report a difference; what is important is whether any difference shows up in his task performance insofar as the task criteria are concerned.

We have had to presume that the operator himself contributed no error to the man-machine system. This assumption is, of course, quite false. But in order to proceed with an analysis we will have to accept certain "givens" in each topic, even though these givens become variables in the next topic.

Some systems of equipment are more subject to variability than are others, although of course variability is always a relative term and it is difficult to find a common denominator on which to base direct, quantitave comparisons.

But we may point out that most gunnery systems, for example, seem to have a good deal of uncontrolled machine variation under operational conditions. The same gun will change in its barrel temperature, rifling, and electrical and mechanical linkages. Differences between one bullet and another will show up in hit error. So if we could substitute for the operator an aiming device which was itself "perfectly" reliable we would still find considerable fluctuation of hit error from one shot to the next, one group of shots to the next, and from one portion of the gun's history to the next. We have been presuming that we are sampling from a universe of actual operating circumstances such as occur in combat, with all the contributing circumstances (such as ammunition, maintenance, target movement) being adequately represented in our samples.

Radar equipment seems also to suffer even yet from a fair amount of what in operatic rehearsals is called "temperament." The same equipment functions differently at different times. Obviously, the more slipshod the maintenance is, the more the same set will vary from one mission to another. Presumably, however, we aim to train trainees ultimately to cope with live operational problems, and not merely with the antiseptic conditions of a laboratory.

Let us refer to the kind of variability we have been speaking of as within-equipment variation. For each sample from a type of equipment, there will be a mean and standard deviation of performance on each variable of its respective outputs. When these variables interact, their individual variations may become compounded into still greater ranges of unpredictability, and the way in which they are compounded may be peculiar to each individual sample of the equipment in question.

It is of course highly time-consuming, difficult, and expensive to determine within-equipment variations, especially if this determination is to be done under operational conditions rather than an artificial laboratory situation. It is always quite safe to anticipate (at least on logical grounds) that the variability values established for the performance of a given piece of equipment will be much larger under operational use than in test use. The total error variance (a measure of variability) of a complex man-machine system will increase according to the well known sum of squares principle.[1]

Unless actual determination of within-equipment variability is determined under suitably representative operational conditions, we cannot know the lower limits of the precision needed to construct a training device for this equipment. Consequently, we will not know how cheaply we can afford to build it.

Furthermore, by building a training device which performs in a more standard manner than a given piece of equipment is likely to perform, we risk a biased training of the trainee by shielding him from ranges of machine variation which contribute to the performance of the task in operations. Adjusting to such variations may be an important part of training.

Between-Unit Variation

Even when two units of the same operational equipment come off the assembly line together, they will vary to some degree in their functional properties. The more complex the equipment and the more complex the situation and variables in which they will operate, the greater these differences between individual equipments. They will differ according to mean values of performance and also according to the variation each shows around its mean performance when subjected to comparable conditions. Thus aircraft Helen of type XD will stall at an airspeed of 70 mph, with a standard deviation of 4 mph, while aircraft Josephine of type XD will stall at 66 mph, with S.D. of 3 mph. A third example, (Dorothy) will stall at a different speed with a different standard deviation.

Our problem is, since we want to train a pilot to fly aircraft type XD, shall we train him on a device simulating Helen, Josephine, or Dorothy? (In the particular example we have chosen, these differences in stalling speed may be psychologically unimportant. The example is merely for illustrative purposes.)

The same sources which make for variability from time to time <u>within</u> an individual equipment will be acting to widen the possible range of differences <u>between</u> individuals of an equipment. The older that an individual equipment becomes, the more likely it will develop individual characteristics as a function of its intrinsic difference in construction, and also as a function of its individual history or experience.

1. The total variance is equal to the sum of the independent, contributory sources of variance. If these sources are not independent, the total variance is equal to the sum of the variances from each source plus the correlational factors. (See any standard statistics text.)

The presentation of the problem of within-and between-unit variation poses significant logical problems to the training device engineers even before we come to the psychological problems. The psychological problems consist of: (1) what are the equipment differences which make a psychological difference, and (2) how important is this psychological difference to training efficiency and transfer of training. A related problem is, how far can training go on a so-called simulator, and at what level of skill or training is it more profitable to shift the trainee to the operational equipment, taking into account our logical problems in sampling equipment characteristics as well as other difficulties in the training situation? We may find that the human being is so insensitive or so adaptable, that what constitute frightening variations in the manufacturing processes of equipment are insignificant in the realistic training context.

Conclusions To The Sampling Problem In Physical Simulation

If one and only one sample of the operational equipment is used as a basis for determining the engineering characteristics of a training device, the particular one unit selected as the model may not be "representative" (have average performance value) of all the other units or items of that class of equipment. Thus the particular F-500 chosen for data-gathering purposes may be consistently more sluggish, or more sensitive, than nearly all the other F-500's which will be used in operations. A device which physically simulates this F-500 will not simulate other F-500's. Thus we risk biased training.

Furthermore, by building a training device more standardized than is operational equipment, we risk a different kind of biased training by shielding the trainee from ranges of machine variation which contribute to the task in operations. Adjusting to such variations may be an important part of training. In actual fact, it is. Pilots do get out of one F-84 and without special "training" fly off in another F-84 which has a somewhat different feel and behavior characteristics.

So we see that even if we accept physical simulation as a legitimate approach to providing a behavioral context for training or performance, we are balked by problems which seem to have no answer in a reasonable economy.

It is true that many of the problems cited above are characteristically ignored by basing the specifications of the training device not on the actual, measured operating characteristics of the operational equipment. The training device is built to the calculated specifications of the operational equipment. The matching of these specifications to what the operating equipment actually does rarely is more than piecemeal, and confined to one or two acceptance and engineering test models. These test models are not necessarily similar to the production models of the operating equipment. Undoubtedly they are better maintained.

Designed by this procedure, the training device simulates not an actual operating device but the specifications for an operating device. Discrepancies may be far more substantial than the close manufacturing tolerances usually imposed on the construction of simulators.

Sampling Of Program Data

Programs consist of environmental circumstances with which the man-machine team will have to cope. We may think of the characteristics of the machine itself as the properties of the display-control or cursor-control system; and the characteristics of the programs as target plus noise properties in the learning problem. Obviously there is always interaction between the cursor-control system and programs. That is, no man-machine operation is performed in an environmental vacuum.

In gunnery, whether fixed or flexible, the target may vary in identity, size, and capacity for evasive maneuver. Combat may occur at high or low altitudes, against the sun or away from the sun, among clouds or in clear skies; if radar is used, countermeasures may be employed or the set may malfunction in part or completely. Each man-machine system has a variety of program variables, and these variables need to be sampled systematically before training can be said to be complete for operational readiness.

The distinction between engineering simulation and psychological simulation applies to program variables as well as to the physical characteristics of the equipment in the man-machine system. In training it should be the aim to provide those cues sufficient and necessary for learning to perform the operational task. These cues may in many cases be less than complete realism.

Physical realism is the relatively safe way to include the sufficient and necessary along with the irrelevant in cues. But it is frequently so expensive that few can be built and maintained, so the large amount of time which the many trainees may require to attain proficiency is impossible to provide. Thus there is lost a principal aim of the training device which is to provide ample practice time for trainees to become highly skilled.

Furthermore physical realism will not guarantee that all important program variables will be represented, or represented in sufficient range, or in sufficient interactions with each other. In visual reconnaissance, one class of programs would deal with reduced visibility due to haze, glare (atmospheric conditions), others would consist of target size, target camouflage, variation in aircraft altitude and attitude, perceptions, of emergency conditions and many others. A visual reconnaissance pilot trained to observe from one altitude would lack important skills for reconnoitering at different altitudes. The combined conditions of camouflaged targets and variable altitudes provide an example of interaction of variables in a program.

In order that the usefulness of the trainer not be severely restricted, there must be capacity for providing programs adequate in kind and range.

But the trainee may learn to make the correct responses to a given practice program after relatively few trials. In order to train him to cope with that kind of program, a greater number of samples are necessary than he can memorize as such, unless operations demand only a restricted set of habits as for example "following of standardized procedures."

Before undertaking to design a device capable of incorporating all programs and tasks encountered in operations, the entire training requirement should be examined with a view to what tasks and programs can be given training in part-task trainers, procedural trainers, part-simulators and the operational equipment. In this way costs can become reasonable and training devices can be produced in quantity and maintained. It is no criticism that a synthetic trainer does not in itself train completely all task requirements to operational readiness--unless the claim of completeness is made for it.

SUMMARY AND SUGGESTIONS

It has been established that physical simulation is a matter of kind and degree. Problems have been raised as to the model or sample to be used in determining the operating characteristics and programs in the design of the training device. Economical solutions to these problems of physical simulation do not seem likely. What is the alternative?

The alternative is to ask, "With respect to a given purpose such as training and transfer of training, how much physical difference makes little or no psychological difference?" We may find that very considerable physical differences are negligible in transfer of training. And this may be especially true of some tasks more than others, and some stages of training more than others. Furthermore, we may be able to train around limitations in physical replication. Finally, we may be able to see the training device and synthetic training in a perspective which is boxed in less by the state of the engineering art than by our knowledge of human behavior.

A number of recommendations can be drawn from this chapter. They are as follows:

1. The design of training devices should be directed towards maximum transfer of training value, not physical realism.

2. Physical realism, both in degree and kind, finally reaches diminishing returns in transfer of training value per developmental dollar.

3. Some stages of training and kinds of task trained require less physical realism than others. Account should be taken of these differences.

4. Tolerances of a variable in the trainer should take into account, and generally not be required to be closer, than the general range of variation found in that variable in tiems of operational equipment. Tolerances required in training equipment should also take into account that the characteristics of the same item of operational equipment vary considerably from time to time.

5. The vital importance of providing practice programs of sufficient kind, range and variety, justifies concentrated attention of the designer. The trainee's range of skill will tend to be restricted to the range and complexity of problems he has met in training.

6. The kinds and extent of physical realism built into a given training device should be based upon careful examination of what is psychologically important versus what is unimportant.

The next chapter is an approach to the design of training devices from the direction of psychological requirements for transfer of training rather than physical simulation.

CHAPTER III

STAGE OF LEARNING AND DEGREE OF PHYSICAL SIMULATION

One does not begin learning a complex job or group of tasks by starting to learn everything at once. There are discontinuities in what is learned and how it is learned. These discontinuities occur spontaneously and they may show up more in some individuals than in others.

In other words, the human learning process consists of a group of processes, some going on at the same time, others evolving from response groundwork acquired through practice on the task.

These stages or phases of learning may determine the kinds and degrees of physical simulation sufficient for effective training and transfer of training both to later training and to operational equipment.

The following pages of this chapter will attempt to relate phase of learning with minimum simulation or other training device requirements. It will be seen that different stages of learning will call for different minimum trainer requirements. But these recommendations should not imply that a different training device should therefore be built for each stage discussed, nor that a training device may not be satisfactory for training if it incorporates more than the minimum as proposed.

Furthermore, in actual learning, many of these phases will overlap each other, or shade imperceptibly one into another. Therefore it would be false to consider the process described in each phase as independent of other phases or aspects of ongoing learning processes.

EARLY STAGES IN TASK LEARNING

The learning of practically every task, whether continuous or discontinuous, begins by getting ideas on what the task is about, and how to go about it. Even continuous tracking tasks have at least brief phases during which they are performed like discontinuous procedures.

We can roughly describe Stage One as the learning of procedures, but not learned by any degree where the task responses are unreeled automatically. The trainee is learning a repertory of self instructions, concepts, and images of what he is supposed to do and under what conditions. Much of this learning can be divided between classroom study, texts, training aids, and trainers which are extremely rough or non-functional copies of operational equipment. In these latter the trainee will get practice in grossly carrying out instructions provided by himself or supplementedby the instructor or a test. During this stage of learning, the instructor will usually be the most economical source of knowledge of results.

Learning What The Equipment Is Supposed To Do

This part of early learning is one phase of what may be called indoctrinational training. Not only should it cover the principal purposes and objectives which the operational man-machine teams are assigned to achieve, but the degree of precision of various aspects of their criterion performance may be presented. How the particular team's work fits in with other jobs in the performance of a mission may also be presented. For example, the relationship of the particular fighter aircraft to the bomber for which it flies as protection would be described.

Unless this kind of information is made explicit to the trainee, he will develop his own hypotheses which may or may not fit the facts.

TRAINER RECOMMENDATIONS FOR TEACHING WHAT THE EQUIPMENT IS SUPPOSED TO DO

1. If possible, experienced operators should demonstrate criterion performance on the OPERATIONAL EQUIPMENT.

2. TRAINING FILM may be used to demonstrate:

   a. The environmental contexts of operations.
   b. The integration of part-task outcomes with other part-task outcomes; or how the output of the skilled operator realistically affects or interacts with some greater system, mission or enterprise. (For example, how the interceptor pilot interacts with ground control operations and with the entire defense system). Actual scenes of action should be integrated with animated diagrams which schematize the relationships.

   c. How one phase of training fits in with later phases of training. The film should include action scenes of actual trainee performance at such stages; the action should include and point out characteristic error and degree of error in task or job performance. Later sequences may show the improvement in actual job outcome.

3. DEMONSTRATION EQUIPMENT: Where possible, simple graphic aids and small-scale models may be used. Automatic operation of moving parts in demonstrators probably does not have much payoff value as against instructor controlled demonstrators.

4. TRAINING DEVICES SUCH AS "SIMULATORS" may be demonstrated by well-motivated individuals who do not perform casually or as if error could not be committed on the device.

Learning what the equipment is supposed to do and the role of the human operator in its performance will have primarily motivational value to the trainee. The indoctrination phase will tend to color the trainee's attitudes and motivations towards training, training devices and training programs. The recommendations proposed here recognize that group morale and individual effort rest on having clearly defined goals and routes and stages for reaching the goals.

Learning The Nomenclature Of The Equipment

Before the trainee can carry out verbal instructions about equipment (including instructions he might give to himself) he must learn to pair the names of objects with the work objects themselves. Thus he learns that video gain knob, altimeter, trim tab control, range reticle, are names for objects he can perceive in his work space. Trainers for teaching nomenclature might be no more than charts or blackboard sketches. If location and simple on-off switching procedures are also to be taught, a simplified mockup made of inert materials may be used. This type of equipment is suitable for maintenance men who use automatic checking devices and make repairs on a black box replacement level. There will also be nomenclature associated with work processes and work products.

TRAINER RECOMMENDATIONS FOR TEACHING NOMENCLATURE OF THE EQUIPMENT

1. Learning of nomenclature can be begun with PICTURES and DIAGRAMS, and continued with NON-FUNCTIONAL MOCK-UPS of the operational equipment. It would be uneconomical to tie up operational equipment or expensive trainers for training on vocabulary.

2. Operational equipment: If, however, operational equipment is normally idle and available, it is desirable and economical to use it for training in both nomenclature and locations of objects. Labelled diagrams or pictures should be accessories provided the trainee.

3. Number of trainers required: Sufficient numbers of copies of the "nomenclature trainers" should be available to permit each trainee considerable practice for learning "naming" habits.

   Without an extremely high degree of skill in matching the object with the word or symbol, the trainee will be confused in following instructions and in understanding and applying criticisms in training.

Locations of Objects In Equipment And In Programs

The trainee must also learn the location of the work objects he can identify and name. The learning of locations and the learning of nomenclature is probably best done in the same training exercises.

The extent to which the trainee can rapidly follow commands in locating and identifying a display or control object will parallel the extent to which he can follow instructions without search and confusion. It will also be the extent to which he can readily imagine symbolic activities when he is given instructions or information apart from his making an overt response.

Much valuable time in an advanced trainer can be saved if the trainee brings to it well integrated habits of locating the objects in his work environment.

TRAINER RECOMMENDATIONS FOR TEACHING LOCATIONS OF OBJECTS

1. PICTURES, plus NON-FUNCTIONAL MOCK-UPS will be adequate for training in locations of objects.

2. Immediate knowledge of results: Learning rate may be increased by providing for immediate knowledge of results. Thus, adjacent to the picture or mock-up there may be a list of the names of objects to be located. Each item in the list has a light and a push-button switch next to it, and each matching item in the picture or mock-up has a push button and switch. When the trainee is learning nomenclature and locations, in the absence of the instructor, he may read the name of an item, press the adjacent switch and note the object beside which a light glows. Conversely, he may press the switch beside the depiction of the object and note beside what name the light glows. He may also use the device for testing himself.

   Such a device would be especially helpful where large arrays of items must be quickly learned with respect to nomenclature and locations.

3. Breaking large numbers of items into smaller groups: Large groups of paired items can be best memorized by breaking them into smaller groups of items. If a group of items can be related to each other logically (as by performing some common or related function), the training aid should group items accordingly. The grouping should, of course, be coded by color, or dotted bands, rather than by changes in normal spatial configuration.

4. Coding of items according to sequence of use: If a group of displays

and controls figure in a series of job responses, the individual items may be artificially number coded. For example, a mechanic may have a standard check routine. If the trainee learns names and locations of objects in the numerical sequence of later use, he will be learning more per unit of practice than by learning items first in random order and later in sequence.

Search And Scanning Methods

It is likely that the search and scan methods adopted and practiced by the trainee early in learning will tend to persist unless actively unlearned and supplanted by substitute habits. In many military and industrial situations total operational effectiveness requires a wide perceptual scope. Under conditions of stress, and similarly under conditions of highly repetitive practice of routine activities, perception tends to become restricted to what have been called "strip-maps" of the work environment.

Thus the gunner while tracking a target should scan lest he become a target to a third aircraft; bombardier and navigator should be alert to gross discrepancies or misidentifications of terrain; the pilot should be aware of other aircraft in his neighborhood; all operators should become quickly aware of equipment malfunctions. But these outcomes presuppose adequate scanning and perceptual search techniques which will not tend to arise spontaneously, nor can they readily be overlaid on other habit systems.

Even part-trainers should provide for keeping the trainee alert to the broader aspects of his work-space than may be required by part-task performance. This provision should almost certainly be included before the part-task is learned to a high degree, but not before the trainee has mastered the locations of objects in his work configuration.

TRAINER RECOMMENDATIONS FOR SCANNING METHODS

1. Stimuli occasionally presented outside the primary work area: Training for scanning habits may be introduced by peripheral signals to which the trainee need respond only by recognition of the presence of the peripheral stimulus. Consequently the engineering simulation may be rough and even merely symbolic; thus in synthetic gunnery training the presence of another enemy aircraft may be denoted by the lighting of weak intensity wheat grain lights to which the trainee responds by throwing some arbitrary switch. The distributor of such peripheral cues should sample from the work-space in which critical cues may appear. These cues should be about as difficult to see (at least in later training stages) as the operational objects.

2. Signals within the primary work area: If a trainee is engaged in practice on a part-task, he also should be required occasionally to

note changes in displays within the work area which are not relevant to the task on which he is concentrating practice. Thus if a trainee is learning to fly straight and level, there may be occasional gross changes in the engine temperature indicator, or the fuel indicator. These display changes may be gross, and even all-or-none, their occurrence should be under the control of the instructor. Response adequacy of the trainee who must detect these conditions may be judged by the instructor.

Learning What Control Affects What Display

Another preliminary phase of learning a new job is discovering and memorizing what controls affect what display features. The term "display" should include both instrumental and environmental sources of cues.

Thus, fore-and-aft movement of the joystick results in a shift in the pointing of the nose of the aircraft (up to a point), or a change in the readings on an artificial horizon and perhaps an altimeter.

Separate training devices would not ordinarily be necessary for this phase of learning. It is possible, however, that if a very complex control board of switches was a part of the operational equipment, some pre-training in the identity of control-display interacters would reduce need for time on more complex trainers.

TRAINER RECOMMENDATIONS FOR LEARNING CONTROL-DISPLAY INTERACTORS

1. DIAGRAMMATIC PHOTOGRAPHS may be used to show connections between control items and display items and provide pre-training.

2. MOCK-UPS OR PANEL DISPLAYS with simple mechanical linkages between control and display will be sufficient to teach verbal understanding of what control affects what display. The mock-up may provide actual practice.

   Usually, this training will actually be included in the phase next described. So, from a practical standpoint, learning what control affects what display and control-display directional relationships may be treated as a single training problem.

Control-Display Directional Relationships

In this aspect of learning, the trainee discovers and memorizes the direction a display changes when its matched control is moved. Pushing the accelerator forward increases a speedometer reading (or rate at which the roadway flows past the field of view); whereas pushing the brake pedal has the reverse effect.

Where only one variable is involved, or no more than one or two controls are within the work environment, and where feedback delay intervals are very short, this phase of learning will, of course, be very rapid. But where this is not the case, as for example in the multiple adjustments which a maintenance mechanic on electronics equipment has to make, learning may require considerable practice.

If the trainee has previously performed on equipment which has reverse control-display relationships, extensive practice may be required under a variety of programs, including time stress, before the old habits get reliably eliminated. Even the disappearance of the old, but now erroneous, habit from one training session is no guarantee of its final elimination. It may recur, though at lesser strength, in later training sessions or operations.

TRAINER RECOMMENDATIONS FOR CONTROL-DISPLAY DIRECTIONAL RELATIONSHIPS

1. Functional mock-ups will be adequate, and physical simulation (including lag) may be extremely rough.

2. Practice exercises could present discrete misalignments of displays which could be zeroed by moving the appropriate control in the proper direction. Dynamic characteristics need not be reproduced.

3. Reduction of feedback lag: If in operations there are lags of more than a few seconds between control action and feedback display, these and even lesser lags could be eliminated in the trainer intended only for practice in these early stages of learning.

> NOTE: A number of training aids and devices have been recommended thus far. In each case, the minimum requirement by way of construction has been indicated. It is likely, however, that the semi-functional mock-up described immediately above would be the best bet, plus a set of labelled photographs, to enable the trainee to get not only familiarity with a complex job through his eyes and muscles, but also to get a fairly clear idea of what he is supposed to do and when. Call it orientation, or pre-training, or learning the elementary procedures--or what you will--this type of practice, if properly monitored or supervised, can reduce much of the trainee's later confusion. This confusion may arise when he must not only know the general pattern of doing a task, but must also properly grade and time his responses, and perhaps also make complex decisions. Because it is difficult to "think of more than one thing at a time" it is necessary to learn by organizing complex response items into patterns. The devices thus far described can be helpful in establishing such patterns by providing the

trainee with the proper exercises. Thus the more complex trainers and simulators can be freed to teach levels of skill which the above devices cannot do, but which usually demand more practice time than trainees are able to get if complex trainers must be used for "pre-training" as well as training.

Elementary Control-Display Ratio

If he is given the opportunity, the trainee will begin to learn the amount of control movement which results in a given amount of display movement or change. Accuracy will, of course, continue to increase until it levels off towards a ceiling at high degrees of skill. With suitable practice, responses will show progressively less terminal adjustment and oscillation especially where a cursor position must be realigned to some changed, steady state as indicated on a display.

The entire matter of simulation of control-display ratio is one of the most important in training. It is risky to make inferences in this area, and research is scanty and far from systematic with respect to type of task, degree of learning, control-display lag and other factors which probably interact with fidelity of control-ratio in transfer of training.

But where discrete control movements produce fairly discrete display consequences, especially without time lags beyond a second or two, it is probable that only gross fidelity in control-display ratio is necessary to maintain optimal training value in early stages of learning the task or job. We may consider this early learning as almost entirely a learning of procedures, even where continuous or tracking tasks are involved, and especially if the trainee is learning to coordinate a number of stimulus-response patterns at about the same time.

Statements on simulation of control-display ratio for middle and higher stages of learning are necessarily complex. These statements are presented in later paragraphs and sections of this chapter, and another general discussion of simulation of control-display ratio is provided in Chapter II.

TRAINER RECOMMENDATION FOR ELEMENTARY CONTROL-DISPLAY RATIO

No general recommendation can be offered. It seems unlikely that an "intermediate" training device with only coarsely approximate control-display ratios would be very economical in a total training picture. It is possible that "part-task" trainers can be developed which would require only coarse control-display ratio and rate relationships. For example, the teaching of aerial reconnaissance to experienced pilots in a synthetic device might require coarse aircraft control-display ratios: presuming that the flying of the aircraft would here simulate the "division of attention" requirement.

Control-Display Ranges

The range effect is shown by the tendency for human judgments to gravitate towards the average of their experiences and to be modified by the frequency and range of values experienced in some variable. Thus the automobile driver who has never driven above 40 mph may be required in an emergency to speed up to 60 mph in order to get through a tight spot. He must judge what speed is called for. However, he will tend to feel that an actual 60 mph is too fast even for this emergency. A hypothetical driver who "always" drove between 70 and 100 mph would tend to judge that 60 mph was too slow for the objective situation which actually --lled for 60 mph.

In order to avoid false range effects which may creep into perceptual "habits," the trainee should probably be given early in his training, some experiences with the full dynamic ranges of the capacity of the operational equipment to respond. The actual limits of these ranges may be fairly coarsely copied, especially since there is likely to be fairly large between-unit variation in operational equipment (see Within-Unit Variability in Chapter II).

Since range effects seem to develop quite rapidly and we do not know how persistently they may effect new experiences, it is suggested that they be considered quite early in training.

TRAINER RECOMMENDATIONS FOR CONTROL-DISPLAY RANGES

1. Programs or exercises in training should occasionally require the trainee to test the "operating limits" of the training device. If these limits are not realistic, the trainee should be given, if possible, demonstrations of what happens at the limits of control-display ranges on operational equipment. For example, what happens when severe maneuvers are performed at near maximum aircraft speeds; what acceleration occurs at sudden maximum increases in throttle settings; or the consequence of rapid reversal of thrust in landing.

   Such demonstrations and exercises are best given after the trainee has acquired the early procedures in operating an equipment. Besides providing perceptual "anchor points" for the trainee, it will take care of his tendency to want to find out the limits of what the equipment can do.

Trainee Attitude And The Glamorous Trainer

Preliminary attitudes of acceptance may be affected by superficial glitter and realism of the training device. Manufacturers, feeling under pressure for general acceptability of their product, may include expensive surface realism even outside the work configuration of the task to be trained.

Thus the shell around some trainers has been glamorized with gleaming chrome and wings and other gadgets irrelevant to the training of responses.

Let us remember that many hot-rod enthusiasts develop much pride in a piece of equipment encased in bent tin. Certainly motivations do not need to be accepted as they are found. Suitable indoctrination of trainees, instructors, and high officials associated with the purchasing program may reduce the need for surface glamor.

After the trainee has passed through his first impressions of the equipment and got down to actual work on it, he will begin to form attitudes of respect towards the amount of work and effort which the training device demands of him. This attitude will be as much a result of method of training as of the training device. The trainee may rapidly come to feel (rightly or wrongly) that this task is a pushover, something he can coast or bluff his way through. Or he may be impressed by the need for mobilizing his maximum effort to meet the training challenge. In any event, his respect for the trainer will come from his confidence in it to train him, the reliability of the trainer, his interactions with the instructor, and his response to the general businesslike atmosphere of the training program.

The outside of the trainer should appear of workmanlike construction and be easy to keep clean.

INTERMEDIATE STAGES OF TASK LEARNING

At this point we may think of the trainee as entering a Stage Two of learning the total job to a high degree of operational skill. He has learned the purposes of the equipment, the nomenclature and locations of displays and controls, some search and scanning methods (which need to be improved and stabilized), and has at least moderate skill in moving controls in the right direction when given signals are displayed to him. He has even begun to make "patterns of response" to complex stimulus situations, but coordination and timing are still uncertain, and reaction times are long.

Much of his perception of signals and motor response is interpreted and guided from within himself by verbal or other forms of "voluntary" mediation. Rather than being controlled in large part by automatic response, his performance is complicated and often confused by many minor decisions. Since he has not been under heavy time pressure, however, these behavioral complications have not seemed very important. He is like the novice automobile driver in a dual control car who must think aloud to himself the individual foot and hand movements which are required to get the car moving. He has been in the protective custody of a skilled driver who is prepared to take over the control of the car anytime the demand of the task become overpowering. However, he has not developed enough of the skill rudiments to do any driving in traffic.

The next major activities will be learning of precision and coordination of movements, serializing responses, perceiving information in larger blocks of information in a unit of time, and the beginnings of responding to rates of target movement. Time pressure now does begin to become imposed as part of the route to the actual time demands of operations.

This stage of learning a complex task may be marked by considerable subjective confusion and response interference effects. These difficulties arise from lack of temporal integration of the processes of perception, mediation and response execution. This confusion and internal habit interference will drop out as more and more processes become semi-automatic and automatic; nevertheless, these habit changes may be very disruptive if pressure is exerted on the trainee's learning rate. One of the signs that this stage is concluded is that the trainee is able to perceive a group of signals as a pattern rather than individual items, as when a telegraphor receives by words rather than by letters, and by phrases rather than by words. The reader who is able to scan ahead of the words he is uttering has reached this level of ability.

With respect to engineering simulation, we will find it increasingly important to copy the precise location of display and control positions and time relationships. Considerable thought must be given now to the "programs," or organization of actual stimuli in time, which present the concrete problems the trainee has to solve in practice exercises. If these programs are too difficult and too extended, the trainee will become fatigued, excessively confused, and discouraged--with impairment of learning efficiency. On the other hand, the trainee should have sufficient challenge presented by these programs to force various of his stimulus-response systems to become more and more automatic so that his decision-making channels are not overlooked.

It is obvious that no general formulas or codes can be prescribed for the training equipment designer, especially at these stages of intermediate degrees of skill. As in the early stages of learning "part-task trainers" may be valuable, but their design becomes more difficult if habits learned on them are to be successfully integrated.

We might first take an overview of the variables and phases of middle stages of learning and then make some comments pertinent to training devices

Perceiving Information In Larger Blocks In Space-Time

The perceptual process seems to develop patterns of response to stimuli. The kind of patterns and their magnitude probably depend in part on the conditions of training and in part on the kind of decision or critical motor response which habitually gets made to the stimulus clusters.

There may be at least two processes at work in the development of perceptual patterning; one of these is in abstracting process, the other is a synthesizing process. We can take them up in turn:

Increasing ease in discriminating task-relevant from task-irrelevant cues: This takes place in reading when we cease to note the special type face or kind of typography used when we read messages. Other examples include the greater ease with which radar operators can identify given cities or terrain items despite visual noise; the speed and certainty with which reconnaissance pilots can identify convoys or artillery emplacements, or navigators can check visual terrain with map landmarks. A related example is the pilot who learns to check-read only a given pattern of instruments which are primary during a given type of maneuver.

TRAINER RECOMMENDATIONS FOR LEARNING TASK-RELEVANT FROM TASK-IRRELEVANT CUES

1. Artificial enhancement of critical cues: In order to speed up this phase of perceptual skill, present to the trainee practice programs in which the abstracting and enhancing of critical or sufficient cues is done artificially.

2. Alternate enhancement vs non-enhancement: Alternate practice on artificially abstracted programs and realistic programs of the same content without artificial enhancement.

3. Putting critical cues in complex backgrounds: Give practice on a wide variety of "noisy" contexts.

   Example suggestions: Training reconnaissance pilots to detect truck convoys. Assume motion pictures to be the medium of presentation.

   a. If possible determine what the best of the trained reconnaissance men can spot and identify under the most difficult visual conditions. This should suggest some of the limits beyond which sample exercises may not be very profitable.

   b. Assemble training exercise material ranging from easy-to-detect to difficult-to-detect target-environment conditions. (The responses of sample trainees should test the material for difficulty of detection of critical cues.)

   c. In the presentation to the trainee of exercises, follow a period of allowing the trainee to find the target with brief, intermittent target enhancement pictures.

   d. After artificial target enhancement in a given exercise, require the trainee to identify the same target from different approaches, different altitudes, in different visual noise, or to other variations in factors important to reconnaissance viewing.

   The same suggestions would apply to radar and navigation training.

Identifying a whole pattern by perceiving any part of it: Another basis on which information can with practice be perceived in larger blocks is that the trainee becomes able to identify a total stimulus complex by identifying only a portion of that complex. An example would be responding to the letters "trggr" as "trigger." This form of perception speeds up the possibility of over-all or main response to complex cue situations.

Such patterning of response obviously eliminates some sources of messages redundancy in cues. But where critical cues are embedded in noise (such as is produced in various operational programs) the trainee may be at a disadvantage if he has not practiced learning to perceive critical cues in noisy channels and thus be able to use such message redundancy as may be available.

Training devices should probably have the capacity to present relatively pure signals which are critical to job performance; but practice on such "pure" signals should be interspersed with practice on the total stimulus context.

TRAINER RECOMMENDATIONS FOR LEARNING TO IDENTIFY WHOLE PATTERNS

Programs of operational "noise" in perception must be obtained through a careful analysis of the job and the environments in which it must be performed. The following suggestions are therefore only samples for illustrative purposes.

1. Synthetic contact flying and landing for pilots: Intersperse in practice exercises poor visibility, haze, smoke, twilight and other factors making for difficult discernment of critical ground cues.

2. Training in the use of radio aids: Include some practice programs of static, interrupted message continuity, sub-standard speech; occasional portions of misinformation embedded in correct information; thus requiring the trainee either to check or to make an inference so as to correct the fault in the message.

3. Radar operator training: A wide variety of noise effects should be included in at least some practice exercises. Such visual noise may be similar to that originating from within the equipment when malfunctioning, or from the environment, including enemy countermeasures. The extent to which such noise should precisely simulate the physical characteristics of operational noise is not known, but it seems somewhat likely that simulation may be only approximate and still have beneficial transfer effects for pattern perception.

4. Navigation training: Similar principles may be applied to practice exercises given in navigation training. Information presented to

the trainee may be inadequate or occasionally even faulty in some exercises.

Training for real life difficulties

It is frequently noted that synthetic and classroom training is inadequate for operations because the trainee is ill-equipped to cope with other than relatively "perfect" conditions. His skills have not included adjustment to the always less-than-ideal work conditions. The more that the troubles, difficulties and errors of the operational world can be introduced into training, especially its later stages, the less must the trainee depend upon "operational experience" and luck to see him through to high operational skill. Perhaps the major liabilities in the real world consist in getting the right information at the right time in order to execute a mission. It is therefore highly important that training expose the trainee to real work problems.

It is also important that the trainee be warned in general that he must expect to cope with such problems in training, and that the purpose is to give him practice, not to thwart him or "show him up". The difficulties should therefore be graded so that he has a better than 50-50 chance (if he has learned properly) to solve the problem with which he is presented. If he fails to solve a problem, he should be shown how he could have solved it.

Perceiving Signals in Advance Of Initiating Motor Activities

The skillful performer is one who "eye is ahead of his hand." The greater the skill, the more flexible the time relationship between perceptual observation of a critical cue and the motor response to it. This is true in a continuous task such as steering an aircraft and in a procedural task such as typing or plotting interceptor courses in a ground control station.

Practice may also lead to perceptions anticipating future stimuli in the way that we "expect" to hear thunder when we see a brilliant flash of lightning If intervening time intervals are marked by intermittent cues (ticking of a watch, passing of mileposts, rattle of a machine gun) estimates of these time intervals may become very precise and, of course, learning them is facilitated.

It is highly adaptive to develop such perceptual flexibility especially where response must be made to complex environments which change at comparatively high speed. The groundwork for such skill will be laid through adequate scanning habits acquired from practice at scanning through all stages of training. The following suggestions provide a basis for increasing the rate at which perceptual flexibility may be acquired beyond that of ordinary practice:

TRAINER RECOMMENDATIONS FOR INCREASING SKILL AT PERCEIVING SIGNALS IN ADVANCE OF INITIATING MOTOR ACTIVITIES

The following statement are provisional recommendations. The methods and devices should be used only after the trainee has had preliminary training at a task and is no longer fumbling with his responses.

1. Dividing attention: During some practice exercises, force a division of the trainee's attention between a primary task and one or more secondary tasks. Secondary task stimuli should be intermittent rather than regular.

2. Avoid looking at controls: Do not let the trainee look at his controls while he is activating them. (Under some circumstances and tasks this may be inadvisable. However, in a time-stress task involving a keyboard or a complex set of switches, the operator should at least learn to look at the next control while he is operating the previous control.)

3. Intermittent presentation of cues: Present the primary cues for a several second duration followed by several seconds of darkness, then several seconds of the primary cues, and so forth.

4. Suitable practice programs: Provide practice programs so that it is possible for the trainee to "look ahead" in a manner similar to what he can do in operations. (The possible difficulty of doing this in some part-task trainers might be one of the training limitations of such trainers.)

> Training note: Suggestive evidence generally points to the conclusion that it is almost useless to try to teach the perceptual skills in a perceptual-motor task independent of the motor performance. It is as if muscle movement were an important part of the total timing mechanism in a given task. Except to teach identification and location of objects, the part-task trainer which abstracts the perceptual components from all motor performance in a perceptual-motor task is not likely to have much training value.

Coordinating Motor Movements

There are several types of motor "coordination":

a. Coordinating a perceived signal with a motor response.
b. Coordinating a pattern of motor responses to be made at the same time.
c. Coordinating motor responses which occur in a series.

All three varieties have in common the reduction of the mediating or voluntary processes and the corresponding increase in automaticity of stimulus-response patterns.

TRAINER RECOMMENDATIONS FOR LEARNING ADVANCED COORDINATION OF MOVEMENT

1. Control configuration: With respect to transfer of coordinated motor responses, the physical configuration of controls now needs to be simulated with exactness, especially if relatively small time for visual search for the control is permitted in the task.

2. Control forces: There is increasing evidence that absolute magnitudes of control loadings are not important to copy either in procedural or continuous tasks if visual or auditory feed-back is available. Although evidence is not substantial for the following conclusion, it would be safe to attempt to maintain the relationships of control forces to each other in those controls which are task-shared and time-shared. But as in other problems of engineering simulation, we should recall that between-unit variability of operational equipment lowers the ceiling on amount of copying which is worthwhile.

3. Adapting to differences in control forces: In any event, the strangeness in "feel" of different control forces while shifting from training to operations will be partly subjective because of different patterns of internal stress. However, even objective differences tend to lose their feeling of kinesthetic strangeness usually in a matter of minutes, especially if the full range of operational response demands is practiced informally. For example, the student pilot when getting into the air after extensive synthetic training, should be allowed to go through a number of maneuvers in rapid succession, but without being subject to evaluational criticism.

   Even if control forces in a synthetic trainer and operational equipment are the same, the former tends to be judged as greater. Therefore, the control forces in the synthetic trainer should perhaps be somewhat lesser over-all than they are in the operational equipment. The matter is, however, of doubtful important to transfer of training.

Serial Motor Responses

People are actually talking about "serialized motor responses" when they speak of "memorizing" the lines of a play, a procedure, or a musical composition.[1] This "memorization" or serializing of response occurs to the extent that each response becomes more and more the sufficient cue for eliciting the next response in the series. Bursts of very rapid groups of responses may occur without support of kinesthetic feedback because of that high rate. Nevertheless, even automatic response chains will inevitably require at least periodic supporting cues from the environment or from the voluntary "intent" of the person, or both.

A frequent disadvantage of automatic response series is that if the trainee attempts to "think about" component responses while he is doing them, or about to do them, the response series blows up. Because of the intensified awareness (self-consciousness) of what one is doing when performing "for keeps" as over against rehearsals, we must expect response chains even well-learned in synthetic situations to become disrupted under test conditions.

TRAINER RECOMMENDATIONS FOR LEARNING SERIAL MOTOR RESPONSES

1. Serialization of motor response in training may be speeded up by increasing the reaction time demands to the limits of what the trainee can do at any given level of skill. This can be done by presenting programs which are complex relative to the trainee's stage of training. Ideally, the trainer should be flexible in permitting the instructor to speed up or slow down the task demands.

2. Transition from trainer to operational equipment: If a skill has been learned to considerable automaticity in a trainer, the shift to an operational device may be accompanied by temporary "self-consciousness" about making responses and verbalizations which will temporarily disturb or even disrupt the trainee's ability to do the task. Either this kind of temporary disturbance should be recognized, or some practice on the trainer should be interspersed with practice on the operational device. Without such provisions it is possible that the trainer's validity may seem to be less than what it might be.

3. Response chains may be more quickly learned if the trainee is encouraged to pre-position his hands and feet on controls as quickly as possible, even when practicing slow programs of control activation. For this reason as well as others, the instructor should be able to view the trainee's manipulation of controls.

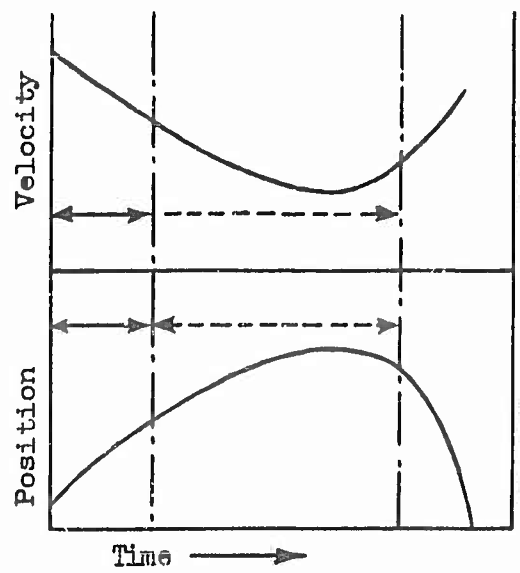
1. Recall that we are including verbal behavior as motor behavior.

Warning: Responses which have become part of a serialized chain are not readily modified without disrupting the entire performance. If flexibility of response items within a chain is desired, practice should not be continued too long on a rote series which does not represent operational variety. One danger of over-practice on a part-task trainer is that responses may become serialized which in the over-all job should be flexible and subject to decision and "judgment" by the operator. This difficulty can perhaps best be overcome by interspersing part-task and total task practice.

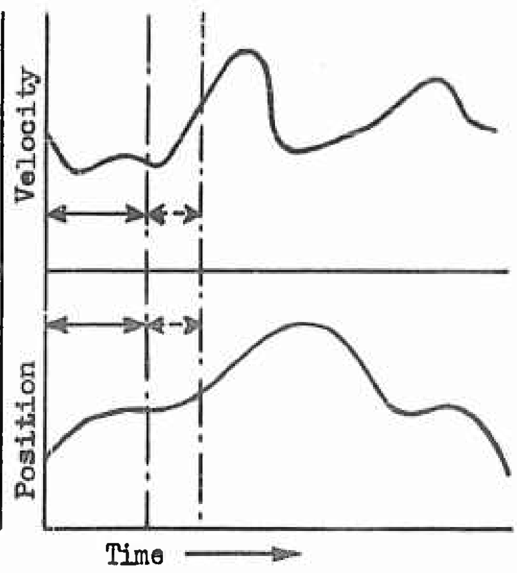
Furthermore, automatized serial responses tend to be anchored to the rates in which the response items were practiced. Change in rates of component response demands will tend to disrupt the entire chain.

Responding To Rates Of Stimulus Movement

When a batter swings at a flung ball his response is compounded of the position and inertia of the bat (which presumably he "knows") and of the direction, velocity and position of the ball (which he estimates). This example is the analogue of the fighter pilot flying an interception course to an evading enemy bomber. Let us think of the bat as the "cursor," and the ball as the "target." The weight, size, shape and balance of the bat we may call "cursor characteristics" and the trajectories of the ball will contain what we may call the "target characteristics."



Sample of "predictable" target course (repeated pattern like a projectile path)



Sample of "unpredictable" target course (fighter aircraft dogfight)

With —— information the skilled operator can predict (with given error) this —— much of the target's future position.

In order to intercept or track a target with minimum error it is necessary for the operator to anticipate its future position from an earlier segment of data up to the present moment. The movement of some types of target is highly predictable (at least theoretically) from even small segments of data. The motions of a flung ball or of other projectiles are examples. The movement of other targets is less predictable (even theoretically)--for example, self-propelled, maneuverable targets such as aircraft and guided missiles may generate continuously changing patterns.

Generalizations about learning and performance obtained from predictable target paths (tracking sine waves or continuous circular motion) should be made only with considerable skepticism to non-predictable target courses.

TRAINER RECOMMENDATIONS FOR TEACHING "PREDICTABLE" TARGET MOTIONS

Some recommendations can be made in the preparation of "programs" for practice in training to track targets whose future positions are relatively predictable, and can thus be extrapolated from a small segment of target data.

1. The control-display time characteristics of the "cursor" (aircraft, gunnery system, and so forth) should be copies to tolerances of between-unit variation. (See page 26 for definition of "between-unit" variation.)

   The control-display ratios of the operational task should be highly simulated if the operational task (1) has a heavy time load of rapid sequential responses, and/or (2) a noticeable control-display time lag.

2. Programs of target courses should copy the rate and rate-of-change characteristics of the operational targets. But the programs should sample also from target courses having motions beyond the limits expected in operations. By motions is meant both rates of motion and maneuverability. Environmental programs should sample from extremes in severity in order to provide the trainee with practice in adjustment to severe "noise."

3. Cues available in operations for predicting more precisely the course of a target should also be available in synthetic practice either directly to perception or at least symbolically.

4. Supporting or context cues available in operations for judging distance, rate and target track should be introduced, if possible, in synthetic training. If this is not practicable, then synthetic practice should be interspersed with operational practice (with "safe" targets, of course).

5. Unique solution problems: Exercises should be programmed to include interceptor problems whose solution is, within fairly small limits, unique with respect to a correct course which the trainee can select. That is, the maximum maneuvering and rate capacities of the trainee's equipment can effect a kill in such air exercise only if proper directions and rates are selected at every phase of the attack pattern. Such practice will reduce the dependence placed by the trainee on the capacity of his equipment to out-maneuver the target at close range. Such a problem might include fuel capacity as a variable.

In order to train an operator to track highly erratic targets, however, it becomes necessary to teach him to extrapolate future target positions from relatively small segments of track information. We are presuming that smoothness of tracking, at least for a number of seconds, is as important as frequency of coincidence of target and cursor track. This presumption is based upon the need of a gun which uses a computer to predict lead angle. A minimum of oscillation or over-control is also required of the trainee.

Teaching the trainee to track erratic courses means that "remembered information" about target courses is of relatively little use; it also means that, for a comparable degree of accuracy, he must respond to shorter segments of presented target data. In short, his perceptual-motor response patterns will have to be stepped up in speed.

In general, a compensatory tracking device such as air-to-air radar, presents to the operator more erratic information than visual air-to-air combat.

(It can be logically demonstrated that the addition of any independent variable to the motion of a target increases the error of prediction based on any temporal segment of data generated by the target. The greater the time between an event A and a prediction of a future event B based on A, the greater the error of prediction. Hence, to maintain a given degree of prediction error when another variable is added to target motion, the prediction must be restricted to a shorter time interval between A and B. This means, for the operator, a more rapid reaction time and less oscillation of adjustments in order to maintain a given degree of tracking accuracy or target kills.)

TRAINER RECOMMENDATIONS FOR TEACHING "ERRATIC" TARGET MOTIONS

1. Range of target programs: Skill in tracking (relatively) erratic targets will be acquired from highly motivated practice at a large variety of erratic target course exercises. Target patterns in these exercises should probably exceed the capacity of known targets to move in erratic patterns; thus they need not simulate the motion characteristics of operational targets.

Because the skill obtained from this kind of practice will be of a higher or more difficult order than skill in tracking identifiable and predictable target motions, provision should be made for far more practice.

2. Interspersing simulated operational target programs: Some practice should be provided occasionally on target courses which at least approximate those which could be generated by actual enemy targets.

3. Variety of target programs: Exercises within a practice session should contain a wide variety of erratic courses so as to avoid the development of any stable "set" to respond in a given way. Such variation will also help determine if the trainee is developing consistent error habits. The target courses should include some relatively easy patterns, not only for motivational purposes, but to allow the trainee occasionally to "see what it looks like to be on a target." An "easy" target course is one approximating a straight line, and in which the target moves slowly relative to the adjustment speed possible to the cursor and the operator.

4. Order of target course presentation: The order of target courses should not be repeated within or between practice sessions. Ideally the trainee would never run the same target course more than once, except for special demonstration purposes. (See note below for other exceptions.) The reason is to rule out his memorizing the courses. Practically, it is usually necessary to repeat target courses in succeeding exercises unless the target course generator is not actually a second instructor himself. It is possible that a complex tracking skill could be learned from 50 to 100 non-repeated courses without memorization of courses occurring.

(NOTE: There is some logical possibility that presenting each target course twice in immediate succession would benefit the trainee at least early in training. Presumably he would be able to incorporate target knowledge with cursor knowledge and have the advantage (on the second run) of seeing a "success". The practical disadvantage would be that the trainee might feel he always had a second chance, and would not try very hard on the first chance at a given target course.)

5. Using response context: In teaching a trainee to track targets, it is essential to embed the exercise between (a) the activity just preceding the tracking and (b) the activity immediately following the tracking of a critical target. Putting the tracking in the job context is especially desirable if precise timing is demanded of the activities, and of the shift from one activity to another. (Recall that a response is determined in part by stimuli acting at the moment and in part by stimuli expected in the future). The fighter pilot who has

no more than two or three seconds in which to pull out of a collision course after firing will have to learn to avoid anticipatory responses which will disturb his perceptions, timing and aim. A training device, free from operational hazard, is appropriate for learning to integrate temporal patterns of response without these patterns interfering with each other. We can realistically expect that the transfer from a non-hazardous, synthetic situation to the hazards of operations will in itself have some disturbing effect on the aiming responses. Such effects will be less disturbing and more rapidly adapted to if aim followed by properly timed pull-out has been practiced in the safe situation.

In summary, practice in a time-critical task should include activities which immediately precede and immediately follow (especially the latter) the critical performance of the task.

HIGH STAGES OF TASK LEARNING

We now will deal with what are obviously the stages of higher learning of tasks and skills. The shift from middle degrees of learning to the high degrees of skill sometimes is shadowy and practically impossible to discern in any actual trainee except over several weeks. On the other hand, there may be sudden spurts of maintained improvement quite evident in a short time. A graduate pilot expressed in simple language the arrival of this degree of competence by saying: "When you are learning how to fly, you have to think not only about what you are supposed to do, but also how you are going to do it. When you really know how to fly, all you have to do is think what you want to do and the airplane does it."

An important distinction of terms must be made. By "high degree of learning" a skill, is meant high degree for some given individual who has been practicing a complex job or task. We do not here mean a high degree or level of skill compared to some other persons. Thus even the poorest pilot of the lot will have acquired "automatic habits," "anticipations," "coordinated response," and so forth. The quality of his performance compared to a criterion may be poor, but the psychological processes nevertheless will tend to take place.

We may also find large individual difference between rate of learning at different stages of acquiring a set of skills. One trainee may be a poor rote learner, so he may be among the slower trainees in the early portions of a training course. On the other hand, he may bring to training excellent perceptual-motor coordinations, so that, if he does not get washed out in early training, he may be among the better trainees in the later stages of training.

The principal developments in very high stages of skill are that (a) responses become rapid, smooth and automatic; (b) the operator is better able to anticipate and prepare for "future" events and becomes proficient in performing to wider ranges of complex programs. These developments are partly due to the increased "channel capacity" of the operator arising from less need for him to think about specific movements he must next perform.

Automatized Habits

Habits are automatized to the extent that responses occur to stimuli without the intervention of self instruction--that is, without having to think about them, such as blinking when an object approaches an eye, or the experienced driver throwing on the brakes when an obstacle looms close ahead.

Behavior is usually automatic only to a degree. Groups of responses may be emitted automatically, but voluntary control (at least in part) may be needed to direct what next group of responses will occur. For example, when a driver first learns to shift gears, he will think, in turn, of the individual response of depressing the clutch, releasing the accelerator, shifting the gears, and so forth. With sufficient of the right kind of practice these individual responses become organized into what we might call the "act" of gear-shifting. By proper training, this act will be capable of variation, such as shifting gears on an uphill grade. Because a response is part of a larger behavioral unit does not rule out its being under voluntary control in another context. The powerful tendency to slam on the brakes when a car is heading into danger can be inhibited by voluntary effort, as it must be on icy roads. The "mental" effort and vigilance may sometimes have to be very considerable, however, to be successful against a strongly learned response.

It can readily be seen that when responses are becoming automatic, they are less flexible with respect to changes in stimulus conditions. The operator may seem to behave stupidly, although rapidly, to the specific cue which triggers the automatic response. We can therefore advise that when responses are becoming automatic, practice should be given in the full range of programs, or stimulus environments, which have a bearing on those response systems. Before slamming on the brake becomes completely automatic to any "emergency" situation, the driver should be given practice on the proper braking for slippery roads, or for going around curves at critical speeds, or for going downhill. Thus he learns to discriminate when one kind of brake response is required rather than another, instead of the wasteful process of unlearning with its often unreliable results under stress.

This consideration is obviously important to the planners of training programs especially if part-task trainers and other synthetic trainers are used. Although many responses must become integrated into automatic habit patterns to make skill in complex performance possible, it is at this stage that the greatest risk of both inefficiency and invalidity of training may arise. Being independent of generalization through mediating processes, automatic responses tend to be triggered by only those stimuli presented in practice, and all those stimuli presented in practice. The trainee may have learned to slam on the brakes at any sudden and unusual stimulus or situation occurring while driving. In one sense, this response may be too specific in that if a stimulus condition develops gradually, he will not brake even when he should. On the other hand, the response may be too general in that some sudden changes in stimulus conditions, such as the squeal of tires and the lurch of a car around a sharp turn at high speed, do not call for slamming on the brakes.

Thus we can see how improper part-training can result in inappropriate kinds of response automatization.

We can increase the rate at which responses become automatic by imposing the following practice conditions:

1. Highly repetitive practice with short rest intervals.

2. Practice under heavy load, that is, making the trainee pay attention to many things (or even extraneous things) while performing the critical response patterns. This will be effective only if the trainee has learned the task to a moderate degree.

3. Practice when the trainee is under heavy anticipations; these may include anxiety and stress patterns. This condition is related to condition 2 above.

4. Practice at speeds which tax the trainee's momentary capacities to perform the responses.

The common factor underlying all these conditions is that the trainee is distracted from thinking about the responses he is having to make while still being forced to make them.

The preceding principles imply that training devices intended to train for response automatization must be capable of presenting programs of considerable variety, complexity and rates of presentation.

TRAINER RECOMMENDATIONS ON AUTOMATIZING HABITS

1. Providing against memorizing practice stimuli: Wide variation in target course patterns are imperative, because the advanced trainee will have better capacity to notice and remember target and signal data. (No longer having to "think" about his motor response, he can direct more of his attention to the environmental stimulus features.)

2. Emphasis on habits of double checking: Training should utilize the capacity for greater flexibility of the advanced trainee's attention by drilling habits of double checking of perception (signal interpretation) and of action (proper control activation).

The instructor is probably the best instrument for training to double-check signal interpretation and response pre-positioning and output. This end can be achieved through directions plus trainee motivation to perform the task at higher degrees of accuracy and reliability. The idea of reliability of performance is difficult to get across to trainees until after they have had some accidents or close shaves due to their response unreliability. It is better that the trainee experience such unreliability in the training equipment. Provision might be made for signaling cue to suddenly change after the trainee has checked it once and shifted his attention to some other cue. Thus if the trainee did not double check the first cue, he would not respond correctly. This type of program is an attempt to simulate the operator's making an incorrect perception and then acting on the basis of incorrect data because he did not double-check it.

There is an advantage to the operator's monitoring his own inputs and outputs. By so doing he acquires and maintains a higher level of voluntary control over his habits. He prevents them from becoming so automatic that he is aware even of their occurrence or non-occurrence. In other words, self-monitoring reduces the tendency for repetitive activities to become entirely mechanical with the almost inevitable degradation which mechanical habit systems undergo. In popular language, self-monitoring enables the operator to keep "knowing what he is doing."

Self-monitoring will not tend to arise as a spontaneous set of habits. Even if self-monitoring does develop spontaneously, it may not be efficient. For these reasons explicit provisions should be made for training of self-monitoring habits.

Anticipatory Response And Time Intervals

Anticipatory modes of response described in earlier stages of learning will become increasingly more reliable. The trainee will probably have learned, among other things, the optimal segment of target information to assimilate per unit of motor response, and this segment will be perceived so as to allow suitable reaction time to the trainee. This situation is somewhat similar to that of the person skilled in reading aloud who learns to "take in" the right number of words at a time, and to apprehend them with the right amount of time ahead of his tongue movements.

TRAINER RECOMMENDATIONS ON DISCONTINUOUS VS. CONTINUOUS TASKS

1. Simulation in discontinuous tasks: When the trainee is reaching high degrees of response automaticity in discontinuous tasks, it is

of greatest importance to simulate locations of controls and displays, display patterns as they occur in space and in time, and any time delays between control activation and feedback cues which call for a next response in a series.

If the response sequences are task-paced, the pacing of the trainer should copy those of the operational device or preferably be somewhat faster, especially if the trainee will have heavy load or stress in operations.

2. Simulation in continuous tasks: When a tracking task involving complex factors, including discontinuous (procedural) components such as switch pressing or voice communications, is becoming highly automatized it is essential to copy programs of displays. Such programs should take into account what the operator has to discriminate rather than all the environmental factors which may be present.

   Example: If the change in horizon curvature with difference in elevation is not used as a critical cue in any task the pilot performs, then it would be unnecessary to duplicate this environmental factor in a visual contact pilot trainer.

3. Display-Control Sensitivity of the trainer should not be greater than that of the operational equipment--a frequent characteristic of trainers. Over sensitivity of the trainer is unduly demanding of the trainee's attention during practice; it may also give the trainee unrealistic expectations of the response capability of the operational equipment in maneuverability. (Sensitivity is the smallest movement of a control which results in a display change.)

   Control pressures and control-display ratios will be somewhat less critical than the copying of the characteristic lags between control activation and display response, even in the higher stages of training.

TRAINER RECOMMENDATIONS FOR LEARNING ANTICIPATORY RESPONSE

1. Copy time intervals: If time intervals must be estimated by the operator as part of his task (as in visual estimates of interception) it goes without saying that these should now be copies with high precision, especially if the task does not provide or permit continuous supporting cues about the passage of time. Often the use of a chronometer by the operator may not fit into the time--or other--demands of the task.

2. Ranges of target movement: The exception to the statement above occurs in later trials on a complex training device (before all training is taken over on the operational device). Here it is recommended

that the trainer should incorporate wider ranges of target movement than occur in operations with respect to velocities, accelerations and spatial patterns.

3. Increased feedback information to the trainee: In these late stages of learning, the trainee is in the best condition for responding to precise knowledge of results information. Because of increased automaticity of response and increased perceptual flexibility (the latter due to his perceiving ahead of his motor response), he has "mental channel capacity" to absorb additional information; and this information may take the form of knowledge of results. Learning feedback may be presented to the trainee verbally by the instructor, or through special equipment channels devised for the purpose. The trainee can now assimilate such information with less risk of blowing-up on what he is doing at the moment than he could during the intermediate stages of skill formation.

Thus the advanced trainee could be given out-of-tolerance data at about the same time with respect to trim, throttle position, altitude and direction. The less advanced trainee might be able to cope with only two such factors at a time.

Furthermore, whereas the less advanced trainee might be given heading information in 5 degree units, the more advanced trainee could cope with heading information in 1 degree units.

Responding to Operational Stress

Before a trainee is operationally proficient he must be a reliable performer in situations where he "plays for keeps". It is the difference between the rehearsal and the live show; landing a simulator and landing the aircraft on the deck; shooting at a synthetic pip and shooting at a pip whose origin can shoot back.

We may think of stress as internal stimulation which competes with the critical stimulus-response processes required by operations. It is a form of "noise" in the operator's private system. It tends to be somewhat more destructive of verbal-conceptual processes than of perceptual-motor processes, especially if the latter are response-cued, that is, triggered off by previous responses in a series.

The training implication is that we may get the trainee used to heavy loads, such as are implied by internal stress, by imposing heavier task loads on the trainee during training than he may usually get in operations. That is, in later training we should provide environmental programs of such complexity that the trainee becomes used to working under heavy signal loads.

Situational stress usually becomes reduced after the first few moments during which the operator is active in operations. It is like the rapid wearing off of self-consciousness of a speaker. This happens unless the performance breaks down altogether. For this reason it is good to concentrate some high degree of practice on the first portions of extended job cycles. This should be done on the trainer especially preceding the trainee's transition to operational equipment when we can expect his nervousness to be greatest and confidence at its lowest.

TRANSITION TRAINING

Transition training is the link between an already learned skill on one kind of equipment and skill in operating a new but related kind of equipment. Major differences between tasks may arise through (a) general acceleration of rates at which perceptual-motor and decision-making response are called for (as in shifting from propeller-driven to jet aircraft especially in landing operations) (b) when reversals of discrete perceptual-motor habits are required, and (c) when new task aspects are added (tail-pipe temperature in jets), or tasks acquire new or increased importance (fuel management in jets).

Carefully prepared task analyses of the old and new jobs should be made on parallel formats. The following kinds of differences should be noted as transition problems:

1. Special note should be taken of the different kinds of anticipations demanded by the new task to patterns of cues which also appear in the old task.

2. Learning new procedures, or an old procedure which has to be performed in a different way.

3. Interpreting old displays in a different way, as for example when different stall speeds occur in the old and new tasks.

4. Modification of all-or-none responses, or responses which have long-delayed rather than immediate feedback.

5. Noticing special signals in the new task, especially if these or similar signals appeared in the old task but did not call for any response.

6. Special discontinuities of critical values in the performance of new operational equipment.

Differences in "critical discontinuities" (item 6) will be especially hard to learn in transition training for the same reason that it is hard to change one response in an otherwise similar pattern of responses. That is, when we have learned a response series like a,b,c,d,e,f, there is difficulty in learn-to say (quickly) a,b,c,p,f, or make other substitutions of one or two items. It would be especially hard to learn "a,b,d,c,e,f." The longer the series which has been learned as a pattern or unit, the more difficult to learn to make a substitution, omission, or addition of response items.

Training should, of course, concentrate practice on these differences. But after rather little "procedural" practice, the practice should be continued (for the sake of efficiency) in the full context of task performance in at least the physical configuration of the equipment around the operator. By "full context" is meant the various behaviors which go on at about the same time in whatever time segment of the job is being trained.

To put it another way, it does not seem as if part-task trainers are likely to have much pay off for transition training beyond very elementary stages of the learning of related tasks requiring different modes of response.[1] On the other hand, part-task trainers might be as useful as in other training situations for the teaching if <u>new tasks</u> for which there was no correlate in the old job.

A special note should be added about transition training. The trainee may show considerable proficiency in the new task, but the passage of time without practice on the new task, or the experience of heavy load or stress in operations, may cause "regression" to old habit systems. For these reasons it is wise to provide for some practice beyond evidence of operational proficiency.

Practice on habit correction should be done on intermittent trials rather than confined to a single block of trials at one time and thenceforth ignored.

Because of the temporary unreliability of superficially well-learned habits in transition training, there should be emphasis on the trainee's <u>double checking</u> his perceptual responses and his motor responses. The vigilance and insistance of the instructor is perhaps the best device for such emphasis; provision should therefore be made for the instructor to view the trainee for the purpose of instilling habits of double checking, as well as for other reasons.

> NOTE: The reader will have noticed that the beginning parts of this chapter were strongly oriented towards training equipment, but that the middle and end parts were more oriented towards programming of practice content and use of training equipment. This orientation reflects the proper concern in the early stages of

1 Unless some <u>time segment</u> of job activities is defined as a "part-task."

learning with the equipment supports for training and the concern in the later stages of learning with the programs of stimuli on which the trainee should receive practice. It is the synthetic representation of programs of target and cursor relationships which can run into major technical problems. These problems cannot be resolved by fiats; they can at best, however, be guided by behavioral principals. For this reason, the relatively concrete and terse design recommendations early in the chapter have given way to more discursive recommendations.

CHAPTER IV. KNOWLEDGE OF RESULTS AND SCORING

Distinction Between Equipment For Training vs Evaluation[1]

Trainers and simulators are designed and used both for training and for evaluation of trainees. In evaluating trainees it is important to have reliability and standardization in the presentation of test exercises so that each trainee will be tested and evaluated under identical or highly comparable conditions. This requirement is not imposed upon a device used only for training purposes. That is, we want to give the gunnery trainee information or cues about his sighting errors which he can use to improve himself; we are not interested in determining whether or not the beginning gunnery trainee has enough skill to enter combat. Our concern in this chapter will be principally with knowledge of results and scoring problems as they deal with the trainee's learning an operational skill.

Summary Functions of Knowledge of Results In Training

Broadly speaking we may think of knowledge of results as any events following a response which the trainee regards as a consequence to that response. Such events may range from "being washed out of training" to a "change in a pointer reading". Knowledge of results may take the form of errors in estimated time of arrival for a navigator-bombardier, time on target for the gunner, a lock-on indication for the radar observer, or safe landing for the bomber pilot. Obviously we will have to have a more specific set of terms. These new terms might as well be rooted in the several ways that a trainee can use knowledge of results in training.

Motivation to learn: For the time being, we will have to assume that the trainee wants to do the job for which he has entered training. But suitable indoctrination must also induce him to want to learn the tasks in the job. There is a difference; a trainee who is motivated only to perform the job may be exasperated with slow practice, although it may be true that only through slow or part-task practice can he acquire and improve his skill.

Presuming that the trainee is motivated to learn, knowledge of results may provide motive-incentive conditions by acquainting him with his improvement in the course of practice. Reinforced by evidence of improvement, he will (other things being equal) want to continue practice.

The trainee usually must be assisted in interpreting gains (and temporary losses) in improvement especially in complex skills so that he does not become discouraged by apparently slow progress. This matter is treated below on page IV-18.

Reward need not be delivered on every trial in order that the trainee will remain motivated. (Money rewards are only paid employees weekly or monthly.) Probably each practice session will motivate the trainee to return more eagerly to the next session if he concludes with some "feeling of achievement" which is rewarding. The human being is capable of responding to delayed reward, and

1. See also Chapter VI, Proficiency Measurement.

many symbolic rewards and interim reward substitutes.

The problem of motivation and specific incentives to learn are of great importance to training and to the kinds of trainer which will be acceptable to instructor and trainee. The problem is, however, outside our scope here.

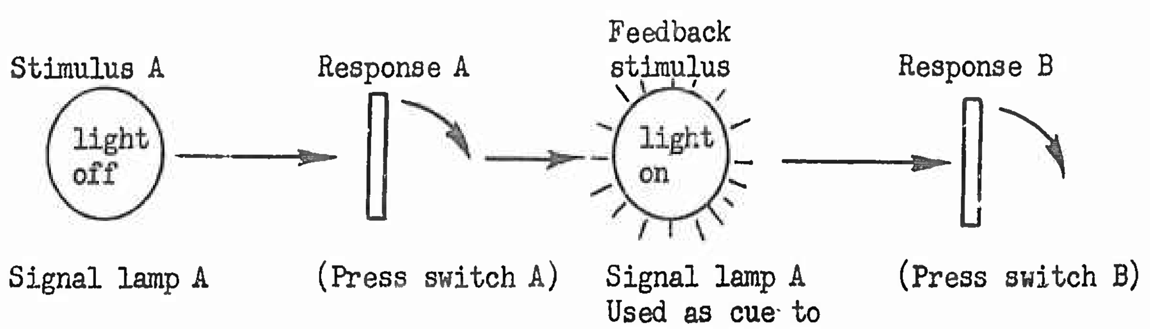
Orient to what next to learn: Knowledge of results may also serve to direct the trainee's attention to some major part of his output which requires special concentration of effort. Thus the bombardier may be informed that his bomb-run procedures are unreliably performed whereas his tracking is at least adequate, or the student pilot may be proficient in stick control but may be lax in fuel management or throttle control. The automobile driver may be told that he is proficient in steering through traffic but needs special practice in parking the car. One of the features of complex tasks is that they may need to be learned with special attention devoted to certain aspects of them at a time. Trainee may need to shift intensive effort from one aspect to another in various stages of practice. Knowledge of results may provide cues to when these shifts should be made.

Information as to what next adjustment to make ("action feedback"): Knowledge of results may serve two important short-range functions, and the distinction between these functions is important:

(a) The consequence of a response may guide the next response.

When it does, we may refer to it as feedback which guides performance, or briefly as "action feedback." We have action feedback in continuous tasks and in discontinuous tasks. The moment-by-moment aiming corrections are guided by what we are calling action feedback: when light A in response to switch A informs the operator that he now should press switch B, light A is serving as action feedback in a discontinuous task. Action feedback is a cue used to tell what to do next in a response sequence.

The situation is diagrammed as follows:

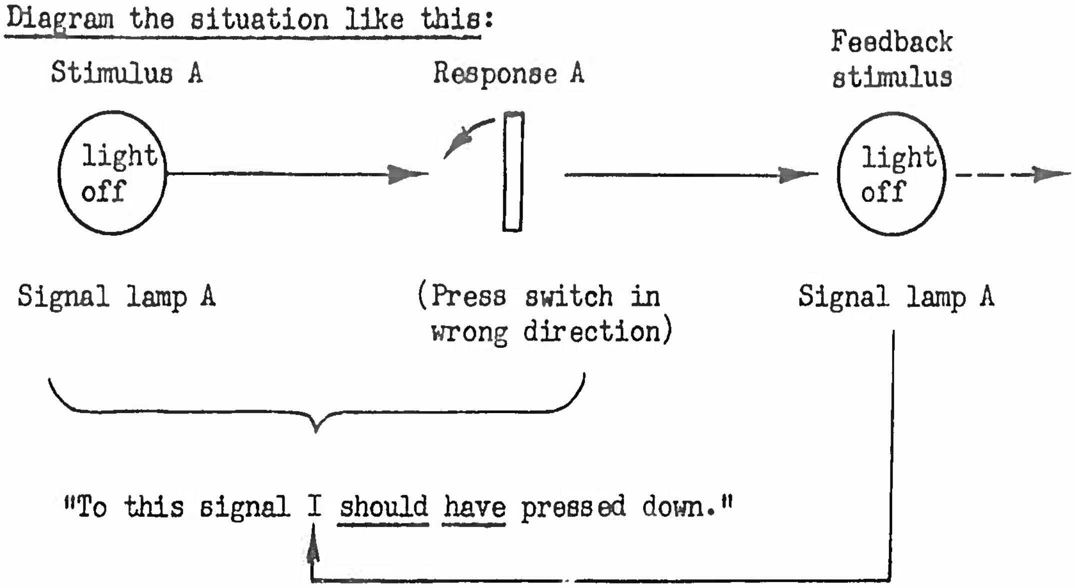


(b) Information as to what adjustment should have been made ("learning feedback"): Response feedback, or error information, may also be used by the operator to tell him what response he should have made (or should not have made) to some previous stimulus.

> A pilot comes in for a landing. He undershoots the runway. The crash informs the pilot that he should have made a different response. If the pilot survives with this information, and uses it so that he does not commit the same error (in kind or degree) we may refer to it as "learning feedback."

Learning feedback is information used to change a response or habit when the same or similar stimulus recurs in the future. It may also strengthen a stimulus-response pattern, as when the trainee observes an indication or response correctness and says to himself, "I see that I did what I was supposed to do."

Diagram the situation like this:



Learning feedback (as we have defined it) helps cut down the trial-and-error process of learning. It makes explicit the fact that symbolic activity "in a person's head" can guide motor responses in the learning process. But it also suggests certain limitations which training should take into account. These limitations will be the subject of a number of recommendations.

The same signal may serve as learning feedback or action feedback, or both, depending on the way it is used by the trainee.

It is axiomatic that in order for a response to be learned to a given stimulus or situation, it has to be made to that stimulus. That is, the pilot of conventional jet aircraft must make the response of reducing control stick forces to the cue of aircraft buffeting in order to learn how to avoid stalls or to recover from stalls. Many young pilots have experienced difficulty after thorough study in classroom and text book. Human beings have the capacity to make symbolic response to symbolic (and actual) stimuli, and in some cases, are able to generalize the symbolic S-R into an actual S-R. This matter was presented in Chapter I. In order for such transfer to be made, however, there must be some kind of one-to-one relationship between the symbolic stimulus and environmental stimulus, and between the symbolic response and the motor response. Thus one can memorize the command, "When it rains I will shut the door." But if the person is unable to identify a door (stimulus) or is unable to perform the responses denoted by "shutting a door," the act will not be performed.

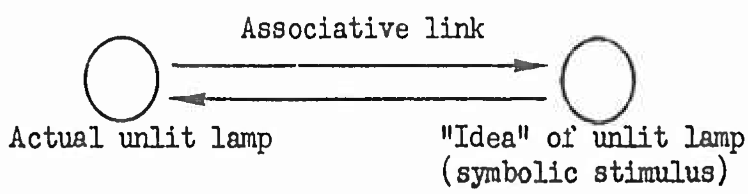
The same principle holds for various degrees of specificity of stimuli and responses.

Bearing these principles in mind, a number of requirements can be set down about the effective use of learning feedback.

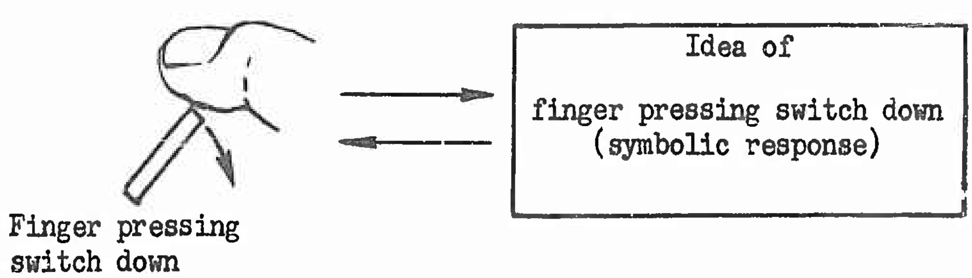
Conditions Necessary For Learning Feedback To Be Effective

To the extent that knowledge of results is to be effective in "voluntary" learning, the following conditions must be set:

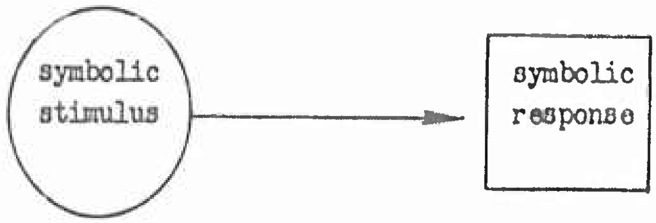
1. The trainee must conceptualize the critical or inciting stimulus in the task. Call the idea of this particular task stimulus the "symbolic stimulus."



2. The trainee must conceptualize the response he did make to that stimulus. Call the idea of this response the "symbolic response."



3. The trainee must conceptualize the relation between the stimulus and the response



4. The trainee must conceptualize a response correction and have the capacity to execute his idea of a correction.

5. The trainee must relate the feedback signal to the relevant stimulus and response which produced the feedback, and do so the next time the stimulus occurs.

The sequence of events leading to response corrections can be shown as follows:

	(1)		(2)		(3)		(4)	(5)
TRIAL 1	Actual Stimulus	→	incorrect actual response	→	feedback	→	{symbolic stimulus; symbolic response (incorrect)}	{symbolic stimulus; symbolic response (correct)}

	(6)		(7)		(8)
TRIAL 2	Actual stimulus	→	{incorrect response tendency / symbolic response (correct)}	→	probability of correct response

This diagram illustrates the mechanism whereby, through voluntary, symbolic activity, a correct response can be substituted for an incorrect response. Repetition of the correct response, especially under a variety of conditions, increases its probability and reliability. Decreasing the time limits to several seconds between events 2, 3, 4, 5 and 6 should increase the probability of the correct response occurring. A very short time interval between 6 and 7 may increase difficulty of substituting the correct response by not allowing the trainee time to "think out" what he should do and inhibit the old incorrect response.

The above discussion generates a number of recommendations for training equipment design:

TRAINER RECOMMENDATIONS

• 1. Delay between response and learning feedback: The shorter the time of interval between response and learning feedback, the better for efficient learning. For tracking tasks as in fighter gunnery this best minimum interval between pointing of the aircraft and information as to accuracy of tracking is 0 seconds but for discontinuous tasks, e.g., turning on and checking radar navigational equipment, there is suggestive evidence to indicate that about 1/2 second delay is optimal.

> Important note: It is both pointless and undesirable to simulate operational delay between response and feedback if the trainee can make no further corrective response in that cycle of work. Thus some bombing trainers simulate time of fall of the bombs before hit indication is presented. Since after bomb release the bombardier can do absolutely nothing about where the bombs fall, it would be desirable to present him with immediate hit information following simulated bomb release.

2. Delay between incorrect response and opportunity to correct the responses: Depending on get-ready periods (foreperiods) for performing a stimulus-Response, the shorter the time between an error trial and a corrective trial, the more likely the corrective response tendency will occur. The training equipment should be able to immediately repeat a certain trial (with its peculiar target track) so the trainee can unlearn the inappropriate responses to that series of stimuli and practice the appropriate responses. For example, when a navigator makes a tracking error during a wind run, the training "flight" should be stopped, the error pointed out and the wind run repeated immediately thereafter.

3. Recalling the critical stimulus: The more completely the trainee can recall the stimulus to which he responded erroneously, the more likely he will reinstate corrective response tendencies. As a practical suggestion, the training situation (device or instructor) may sometimes warn the trainee that the critical stimulus is about to appear. The artifical warning should be discontinued within a trial or two after the trainee has responded correctly.

4. Symbolizing the stimulus: When presenting feedback, the more the critical task stimulus is symbolized rather than actual, the less likely there will be functional or effective recall of the actual task stimulus. This is one major limitation of a graphic or permament record. On the other hand, if suitable reaction time is allowed for symbolic associations to operate, the principle may have less practical value than is afforded by the flexibility of using symbols. Debriefing sessions do provide valuable training, even though the words are only symbolic of actual events occuring in maneuvers.

Pre-training In The Use Of Learning Feedback

Symbolizing stimulus, response and feedback signals: Verbal pre-training (or other symbolic equivalents) of specific stimuli, responses and response feedback signals will increase the ability of the trainee to profit from "learning feedback." This is especially true if there is substantial delay between the S-R in the task and the presentation of the feedback.

Identifying sources of indication of response adequacy: The trainee will profit from pre-training in looking for and identifying sources of cues which can serve him as learning feedback -- that is, as indicators of response adequacy.

Identifying An Error Signal

TRAINER RECOMMENDATIONS

1. Ease of identifying the signal: The more readily and clearly the trainee can identify a correct from an incorrect response, or an on-target from an off-target situation, the more rapidly can learning of a task or sub-task occur.

2. Distinction between feedback signals: The more readily the trainee can distinguish feedback signals arising from one set or mode of responses from feedback signals arising from other sets or modes of response, the more rapidly he can learn. It would be easier to improve dive bombing performance if the trainee were told that he released his bomb at too long a slant range or did not make sufficient lead allowance than if he were simply told that his bomb fell short.

In many training situations the instructor assists the trainee to identify and distinguish among feedback signals. Training equipment design may help the instructor by providing artificial enhancement of specific learning feedback cues to the instructor and to the trainee (providing the latter will not use it as an "action feedback)." (See page 72.)

3. Strength and duration of learning feedback cues: Learning feedback cues presented early in learning should be of sufficient strength (signal-to-noise ratio) and duration to permit the trainee to interpret the signal and relate it to the appropriate S-R.

The equipment supports for this type of practice may need to involve no more than appropriate ON/OFF switches in the instructor's station. For a continuous task a FREEZE switch can allow the instructor to stop the current program to the trainee at any time. This device has already been used in gunnery and navigation.

4. Precision of feedback information: Tolerable or scorable error should not impose a ceiling on what the trainee can attempt to do in eliminating his error. Mere hit vs. no-hit information is usually too crude to provide maximum useful information to the trainee. And even though hit scores may be in terms of a 5 Mil target, the trainee should be able to try for smaller error by being shown the position of his his hit within the target perimeter unless doing so is hostile to some other training purpose.

Self-perception of error: The trainee should be encouraged as early as possible in training to identify error signals by himself for learning purposes. For example, the fighter should learn to recognize an excessive G-suit force as an indication that he is about to exceed G force limits. In this way he can maximize the usefulness of practice both in synthetic and operational performance.

Especially during the early stages of practice, the trainee's ability to learn to recognize error signals is inversely related to task pacing imposed by the instructor or the equipment. Self-pacing of tasks has some pay-off early in learning to recognize error signals.

5. Feedback pointing to stimulus component of task: In general, the instructional situation should direct the trainee's attention primarily to the stimulus (or the mediating concept) and secondarily towards the critical response as such.

Example: The instructor telling the trainee "When you have passed a car and before you turn back into the right lane, (stimulus), be sure to look in the rear view mirror to see that you have passed the car."

TRAINER AND INSTRUCTOR RECOMMENDATIONS

6. Damping excessive response oscillation: In early stages of learning a tracking task the trainee should be encouraged to disregard minor deviations or errors if his attempts to correct for them lead to over-corrections and oscillation of machine output. It may actually be desirable to introduce some artificial damping effect into the action feedback presented to the trainee during early practice. This damping should be removed by middle and late stages of learning.

Example: The continuous jiggling of the steering wheel by the novice driver.

As a corollary, in continuous tasks the instructor should, where safety permits, allow time for the trainee's error to become large enough to be readily perceived, preferably without calling the trainee's attention to it.

Verbal instruction about error signals: Verbal instructions may be at least temporarily effective in aiding the trainee to learn to identify error or feedback signals.

> Example: The instructor telling the engine mechanic, "As you are adjusting the carburetor watch to see if the exhaust is a light blue."

Using Feedback Information

GENERAL RECOMMENDATIONS

1. Interpretability of feedback cues: It is useless for learning purposes to present the trainee with learning feedback from which he cannot interpret what the correct response should have been. That is, the trainee must be able readily to infer from the feedback signal (which may include the instructor's remarks) what kind of response correction should be made in future trials.

2. Matching specificity of feedback with stage of learning: The amount of learning feedback which can be perceived and remembered per unit of performance will obviously differ from one stage of learning a complex task to another. Rather than confuse the trainee by giving him more information than he can use, it is better to allow the equivalent of part-task practice in given blocks of trials, concentrating feedback information on:

   a. His systematic rather than occasional errors

   b. Response systems which are retarded compared to his other aspects of response in the task or job

3. Overburdening the trainee with excessive learning feedback: To the extent that the trainee cannot put into effect in later trials the learning feedback information presented to him, the excess feedback acts as noise interfering with perception and later recall of such information as he might have used. Practice and learning feedback should therefore consist of those segments which, for a given stage of learning, maximize the trainee's making of correct response when he is performing at the limit of his momentary capabilities. This requirement often means simpler starting exercises than is common in training, and more frequent rehearsal of such simpler exercises, but with shifts of emphasis among blocks of trials from one performance variable to another. For example, the pilot who is transitioning to jet bombers may be taught check procedures, flight control during takeoff, and throttle control to achieve maximum performance separately. The nomenclature, operating principles, and manipulatory skills would be very difficult to learn if equal emphasis were given to all three areas at one time.

Trainee's verbalization of correct stimulus-responses: The training situation should encourage the trainee to verbalize what correct response he should have made to the task stimulus when he was in error, and the correct response he did make to the stimulus when he was successful. Such verbalization should be monitored (as by the instructor). By verbalizing aloud it can be monitored, and will be better remembered, at least as a verbalization. This principle emphasizes the importance of good facilities for voice communication between the trainee and his instructor.

TRAINER RECOMMENDATION

1. Importance of eliminating directional error in performance: Because of its all-or-none character, the elimination of directional error in a response will generally be more difficult than learning to change other response components such as magnitude and rate. This is especially true if the response is one of a response-cued series. Special attention should be given to inform the trainee quickly of direction errors such as if he flipped a switch in the wrong direction at a given time.

> The importance of this consideration arises when a trainer is being designed to transition from one aircraft to another. Suppose the in-out positions of the speed brake switches of two airplanes were reversed. On entering certain steep dives failure of the brakes to extend might well be fatal.

2. Occasional sampling of total task performance: The programming of practice and the presentation of knowledge of results information should be designed to search throughout the trainee's entire task repertory at frequent intervals during part-task practice. This search should permit the discovery and elimination of incorrect response tendencies before they become too strongly learned and generalized.

3. Occasional self-pacing of task by trainee: The training situation should provide for occasional practice trials in which the trainee can set his own pace for performance. Discontinuous tasks should profit more from such self-paced trials than continuous tasks. The trainee should have, on such trials, ample time to recall and verbalize what he is going to do next from one step to another.

4. Shifting from part-task to total-task context: If a part-task trainer is used to correct habit systems, practice on the part-task should frequently alternate with practice of that part-task in the total task context. This will tend to guarantee that what is being learned in part-task practice will transfer to the total task context. Practice of corrected response should always be made to a variety of situations before it can be considered reliable.

5. Permitting the trainee to review his responses in task context: Two general methods may be used in training equipment design to help the trainee focus attention on his performance with a view to the specific operations whereby he can improve it.

Sufficient time may be allowed between cycles of practice so that the instructor may emphasize the review of successful vs. unsuccessful components of task responses and the cues to which they were made. This period of review should probably follow each cycle when it is longer than, say, a minute, but after alternate cycles when the task sequence is shorter. If possible, breaks should not come when the trainee has task-directed anticipations, such as midway in a simulated aerial attack pattern.

If it is necessary, however, to break up an undesirable habit pattern which is becoming stabilized within a practice cycle the instructor should have a FREEZE switch which renders all displays and controls static. Thus the instructor may interrupt a performance in order to demonstrate some specific inadequacy which may be difficult or impossible to show at the end of the cycle, or be unconvincing to the trainee.

The instructor should be cautioned to use the FREEZE control rarely and judiciously, or the highly motivated trainee may become disturbed throughout practice.

Operational And Artificial Feedback

An important distinction should be made between feedback information which is in training substantially like that in operations, as against feedback provided in training which is characteristically absent in operations. The latter may be thought of as artificial feedback and the former as operational feedback.

Examples of artificial feedback include the comments made by the instructor about the trainee's performance, or some special signal not normally in operations which indicates to the trainee when he is on-target or off-target.

Artificial feedback may often function either as action feedback or as learning feedback. When the instructor tells the trainee, "Now is the right time to put in trim," the instructor is presenting artificial action feedback from the trainee's previous response. But when the instructor tells the trainee, "When you were making that turn you should have increased your throttle setting," the instructor presented artificial learning feedback.

These distinctions are far from academic as we will see in some of the following principles.

Dominance of action feedback over learning feedback: Where a single artificial or operational feedback cue can simultaneously act as both learning and action feedback, the trainee will tend to respond more to the action feedback aspect of the cue. A continuous tracking task produces feedback to which the trainee may respond either as action feedback or learning feedback or both. It is a challenge to the inventive ingenuity of the designer of training equipment to devise a method of presenting effective learning feedback (as such) to the trainee which does not violate the following finding.

Artificial cues combining both action and learning feedback: When a trainee has become dependent on an artificial cue as an action cue during training on a continuous task, the removal of that cue tends to deteriorate performance to about the level which would have been reached by similar practice without that artificial cue.

> Example: A number of studies in gunnery training have provided for the reddening of a target when the trainee was on-target. The reddening of the target was an artificial feedback cue. When, the target was not reddened, after a practice series, the performance of those trainees dropped back to about that of the control group who had equal amounts of practice without the artificial (target-reddening) cue.

TRAINER RECOMMENDATION

Although this problem is not yet a closed issue, it can be said that results to date do not justify introducing artificial cues which the trainee can use as an action cue, that is, to guide his next response. It is possible that occasional trials with such artificial cues may have good motivational effect.

But where artificial feedback can be used by the trainee only as learning feedback we should expect improvement in trial-by-trial performance, other things being equal.

> Thus the projection of target path and cursor path (hit path) immediately after a practice attack should be beneficial. How beneficial it would be would depend on the extent to which other principles cited in this section may have had their requirements fulfilled.

Dominance of dramatic cues: The trainee in the training situation will tend to respond to the most dramatic, easily discriminable and (to him) most reliable cues. Stimuli which have strong contrast to their background, or which are sudden in onset, or move rapidly, will tend to be dominant. Cues arising from actual objects (earth, horizon, apparent size of trees and houses) will tend to be dominant over symbolic cues (artificial horizon, altimeter) unless special training is directed towards reversing this dominance. (This point is of particular significance in planning the programs of contact trainers, or visual reconnaisance trainers.)

TRAINER RECOMMENDATIONS

Learning to disregard misleading cues: If the trainee must learn to disregard certain dominant or habitual but misleading cues, it is necessary to introduce such cues in frequent training exercises.

Unreliability of cue associations: If two feedback cues X and Y are equally relevant to the performance of a training task, it should not be necessarily assumed that because the trainee uses one of these cues successfull, he also has learned to use the other cue.

> For example, night driving offers at least two sets of cues for steering a car, the center line and the right edge of the road. Both cues are almost always present. Drivers may become proficient in guiding their car by one, but be uncertain and somewhat erratic when forced to depend on the other. The availability of cues in the past does not guarantee that responses have become associated with them.

Learning to respond to several types of feedback cue: If the trainee must learn to be able to respond to either or several types of cues, some practice exercises should omit all but one type of cue; other exercises should omit all but the other type of cue.

Reinforcement of partially inadequate modes of response: Responses should not be rewarded if they are made in a manner which will interfere with higher degrees of learning the task. (At least, practice with such reward should quickly be discontinued when the response component being trained at the moment is even moderately well learned.

> Thus the trainee gunner (flexible) may be rewarded with high hit scores on a training device which does not penalize erratic movement. The trainee can get high hit scores by such erratic movement as would, on the operational device, produce large inaccuracies in lead angle through the computing mechanism. High scores should indicate and reward modes of response which are essential to good criterion performance, not modes of response which are contradictory to it, or some aspect of it.

Spurious Cues

A spurious cue is one which unintentionally occurs in the training situation but is not in the operational situation, and to which the trainee may make, or try to make, systematic responses. For example, the audible click of a relay in an electric chronograph when the trainee is on target, or the reaching motion of the instructor visible to the trainee when the former is throwing a "trouble" switch, may guide the trainee in a way not appropriate to operations.

Spurious cues may be random as well as systematic within the context of the training task. As a hypothetical example, occasional power surges manifest in the lights or general illumination may remind the trainee to scan or perform some other job activity. Although such fluctuations may be random during practice, they may uniformly elicit scanning responses which the trainee might not make in their absence.

In some circumstances, often not predictable, the human organism is highly sensitive to habit formation to even very subtle cues. The trainee who is motivated to "beat the training situation" will be especially alert to such cues and try to fit them into his hypothesis of how to beat the machine or the instructor.

TRAINER RECOMMENDATION

It is worth considerable effort to eliminate both random and systematic spurious cues perceptible to the trainee and especially spurious cues <u>if the trainee can</u> (or is likely to) <u>use them</u> to guide his next responses (that is, as action feedback).

<u>Dramatizing Learning Feedback</u>

Although artificial cues may be undesirable if the trainee can use them for action feedback, special cues may be helpful in emphasizing learning feedback if they cannot also serve as a cue for action. It may be quite desirable to dramatize a successful bomb hit, or a simulated hit on an enemy aircraft in synthetic gunnery practice, or any other termination of a task cycle in which response has been highly successful -- or the reverse. On some flight simulators there is the sound of a huge crash and harp music to dramatize the trainee's diving the aircraft into the ground. The harp music may be of doubtful worth because it may introduce humor into what should be a grim situation, and thus distract the trainee from memorizing the cues and <u>corrective responses</u> which would avoid such failures in future practice.

Finding the middle road between overdramatizing learning feedback, with its risk of distracting the trainee from analysis and later recall of error, and the often feeble sense of "closure" or task completion obtained in a synthetic training situation, must be left to the individual case. Dramatic feedback will probably not aid learning <u>per se</u>, but it may have motivational importance in bringing the trainee back to the next practice session or cycle with interest. This may be especially true if the task or stage of learning permits relatively small ratios of success to failure.

We may remember that to adults as well as children it is more interesting in target practice to hit a bottle than a piece of board, and a glowing electric light bulb than a bottle.

<u>Scoring and Tolerance Graduation</u>

A scoring tolerance defines the limit between a response considered a "failure" and one considered a "success." Or the distinction may be between a "hit" and a "miss." Such scores help the trainee interpret whether he is doing satisfactory or unsatisfactory work in a given practice cycle, session or part of a course. Since these are value judgments, they are in the area of trainee motivation.

> Note: The reader is reminded of this distinction we are trying to make between "information about his error (informative feedback)" and an evaluation of the significance on "success" of his performance which we call a "Score." A gunner may see that he is 10 mils from target point without being given a score of success or failure.

TRAINER RECOMMENDATIONS

Ratio of hit-versus-miss scoring:

1. In order to keep the trainee interested in trying to improve, our best bet seems to be to offer him about a fifty-fifty chance of getting a success or failure in any trial where he is competing with himself. Individual differences might change his optimum figure which, in any event, is only a best guess.

2. If the trainee is one of a class, it may be more realistic to select the scoring tolerance so that fifty percent of all tries in the class during a given stage of skill are successes and fifty percent are misses on the basis of daily scores. It would certainly be undesirable for any trainee to have either practically all hits or all misses during his trial-by-trial practice.

3. In order to maintain a more or less constant ratio of hit-miss as skill increases, it becomes necessary to make scoring tolerances smaller. The training situation should therefore be flexible in this respect.

4. It should be strongly emphasized that the 50% chance of hit scoring should be used only within a practice session where a number of trials occur. Scores at the end of the practice session should reflect progress towards the criterion as described in the next paragraph.

TRAINER RECOMMENDATIONS

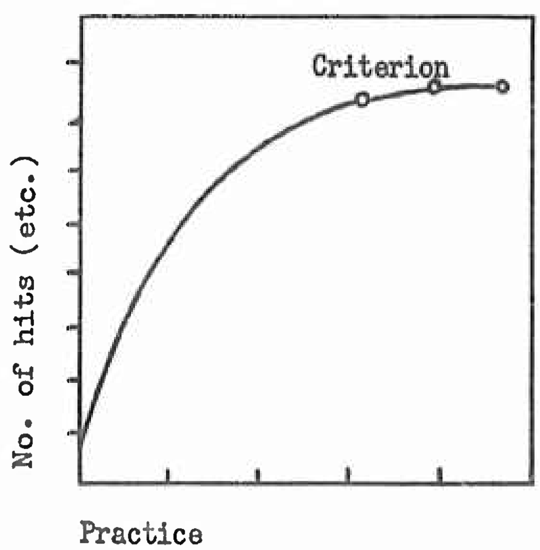
Scores reflecting progress towards the final criterion:

1. Scores denoting progress in learning will primarily have motivational rather than informative significance. If they are made available, they should probably be shown at the end of the trainee's practice for the day or at least prior to his next practice session. Such scores ideally would show not only the trainee's mean performance, but also his variability (reliability) of performance.

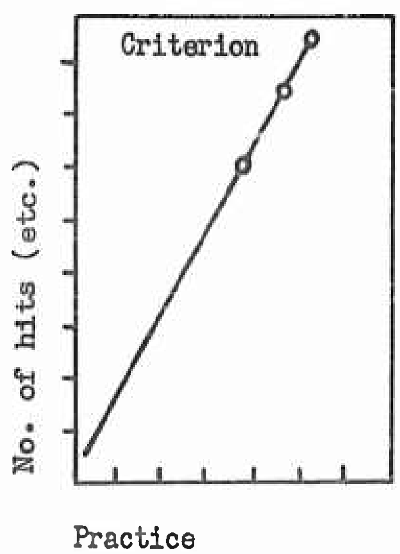
2. Scoring units must be fine enough so as to reflect improvement over considerable periods of practice; on the other hand, they must not be in units which are overly sensitive to chance fluctuations. The question cannot be solved purely on logical grounds; empirical data are necessary.

3. It is also helpful to identify a final criterion for performance. This criterion may be based on the performance of top-level operators or trainee graduates, or it may be based on some criterion acceptable to the user of the trainees who have graduated. A criterion of final performance anchors the goal of practice.

4. Learning curves characteristically show rapid improvement in earlier stages of practice, and smaller increments of improvement per given unit of later practice. The small apparent improvement reflected in positions on the curve in later practice may be discouraging. If an empirical improvement curve on the task is available, it might be modified so as to take account of the increasing difficulty in attaining given increments of improvement. Graphically this would be no problem. It would require stretching the units on the ordinate at the upper end so as to change the empirical negatively accelerated curve into a straight line. Normative data on training the task would be required in order to obtain the empirical curve.



Standard Improvement Curve



Modified Curve

5. The simplest method of converting performance data into any kind of evaluational or normative score is to provide the instructor with appropriate conversion tables.

<u>Excluding Machine Error From Informational Feedback</u>

To confound information about which the trainee can take corrective action with information about which he can do nothing is obviously inefficient for learning purposes. It is partly because a synthetic situation often can eliminate random machine error inherent in operational equipment that synthetic training can be more efficient than training in operations.

> For example, there is always substantial random error in gunnery equipment. When the operator fires a weapon in operations, his own aiming error is confounded with the gun error or unreliability. To include the gun error in knowledge of results dilutes the adequacy with which the trainee can possibly take corrective action the next time he aims the gun. Since the purpose in training is to teach him to aim the gun to the best of his ability, only point-on-aim information should be returned to him.

TRAINER RECOMMENDATIONS

It should be emphasized that the recommendation is to eliminate *random* machine from informational feedback to the trainee. Constant or consistent machine error, by definition, is a kind of error for which the trainee can and should learn to compensate.

There are two qualifying conditions to this assertion.

1 1. If the trainee will acquire a false expectation of success in operations because he was trained without random machine error, the trainee should be given either practice or indoctrination which will make his expectations realistic in operations. This practice or indoctrination should occur after he has reached a high degree of skill in the synthetic task, since we do not expect the situation to be optimal for learning.

2. If, following training on a "perfect gun" or other equipment, the trainee erroneously attempts in operations to compensate for machine errors added to his own aiming errors, there should be a transition phase of training. This transition phase should follow a high level of skill in aiming the "perfect equipment." Machine error at least roughly comparable to that of operational devices should be introduced in order to acquaint him with the perimeter of the zone of error about which he can do nothing (and should do nothing if *smoothness* of tracking is important) by way of compensatory response.

Another reason for introducing some practice in the context of the total man-machine error system is that he will not be led into foolhardy risks on one hand, or become unduly cowed or timid on the other. We should not expect great gains in aiming skill, however, after this introduction of machine error if the machine error is a sizeable component of the total system error.

> (For a more thorough treatment of this problem see Miller, Robert B., Memorandum No. 1, *Operational Equipment Error Systems in the Training Equipment*, 29 July 1953, a supplement to *Handbook on Training and Training Equipment Design*. Copies of this memorandum are available from the Psychology Branch, Aero-Medical Laboratory, Wright Air Development Center, Dayton, Ohio.)

Determining What Information To Feed Back To The Trainee

(a) List the task variables (discriminations, decisions, motor activities) which the trainer is intended to train

Action feedback: The first step should lead to the task analysis of operations. From it we determine what action feedback in operations guides responses one after another within a task cycle or job segment. There is no choice but to represent these in the training situation whether to some degree of realism as they occur in operations, or symbolically. They may be symbolized in the form of a statement by the instructor, or they may be coded into some display shown by the training equipment.

> Examples: A procedural task in which a number of switches must be thrown in a standard sequence. At each throw of a switch in a mock-up the instructor may say "Correct" or "Incorrect." Or a special tel-light in the mock-up may inform the trainee that his correct throwing of a given switch now authorizes his throwing the next switch in the task series. In operations, the successful order of throwing switches results in the feathering of a propeller without engine damage.

As noted elsewhere, action feedback may also serve as learning feedback.

Learning feedback: From the task analysis determine those discriminations and motor responses in the operational task for which action feedback (paragraph above) is not in itself sufficient information to tell the trainee whether his previous response was right or wrong, acceptable or unacceptable. That is, a final machine output may be the joint result of a response pattern or sequence. In radar bombing, for example, the final machine output is the circular error of the bomb hit. But the circular error does not reveal to the trainee which of his several procedural or continuous activities contributed to the deviation from the target center. Analysis of trainee response error must be provided in this case either by instructor or artificially by the trainer.

When these response components of the task have been abstracted, the designer will have to decide whether it is more practicable for the instructor to be the error observer and source of corrective information, or whether the training equipment, or some combination of instructor plus signalling method is most practicable.

In this way, tentative provision for correction of error is made for all essential response requirements in the task. The particular way in which the equipment displays the information to the trainee is a later step in human engineering.

(b) Determine the performance tolerances for the stages and phases of learning through which the trainer is intended to carry the trainee.

(c) Determine (tentatively if necessary) which of these variables will have instrumental assistance to the instructor by his having information about them automatically discriminated, coded, stored or communicated.

Concluding Statements

The principal concern of the designer of training equipment about feedback to the trainee may be summarized as follows:

1. What are the minimum types or channels of "learning feedback" which will be most helpful in getting the trainee to reduce or eliminate his errors?

2. How can "learning feedback" be emphasized and presented to the trainee, but without its being used as a crutch for "action feedback"?

3. Is the instructor or the equipment likely to be the most efficient and economical means of (a) noting response error and (b) informing the trainee about it as learning feedback? If the instructor is to be used, what does this mean to the design of the instructor's station? These problems must consider the total load on the instructor during the time he may have to notice and communicate. Obviously the use of the instructor offers flexibility and economy (unless more instructors are thereby required); the use of equipment entails greater reliability and objectivity.

4. How can information be presented to the trainee so that he can best use it to improve his habit systems in his repeated practice trials?

And finally, it is important to distinguish between problems which center on the following: (1) feedback to the trainee which enables him to improve his specific response patterns, (2) evaluation of the trainee with respect to norms or to other trainees, and (3) scoring considerations involving trainee motivation to learn. The problem of trainee evaluation should not obscure the prime importance of how to get the trainee to learn most rapidly and with maximum transfer value.

The adequacy of plans for handling knowledge of results may be determined from the reply to the following question:

> "Can the trainee quickly and meaningfully find out whether any crucial responses he is making are within or outside each of the quality standards required of the tasks?"

For each behavioral step or task variable the designer should be able to write in a "Concrete Indication to the Trainee of Response Adequacy or Inadequacy."

CHAPTER V. RECORDING PROCEDURES

Distinction Between Teaching And Evaluational Purposes

Recording of trainee performance provides a "memory" for scores. This "memory" may consist of a permanent or semi-permanent record. The recording of scores for training purposes may require different data than recording for evaluational purposes.

Recorded Data As A Help In Teaching

Recorded data may serve as a direct aid to the trainee or primarily as a direct aid to the instructor. Each of the four following topics briefly discuss how they may provide such assistance, and suggest recommendations for trainer design.

1. Showing constant versus variable errors: The comparison of records of performance over a number of trials or practice sessions over similar kinds of exercise may reveal that the trainee makes some errors quite consistently, whereas other errors are not consistent. The instructor and trainee will usually want to concentrate on those habit patterns which consistently produce undesirable results. If the recording permits such analysis readily to be made, it provides obvious help in making such decisions.

> Example: A student gunner has a pattern of shots in successive passes at a target: seventy per cent of his shots are to the left of the target.

2. Showing continuities of trainee response: The response outputs of the trainee may be so complex that an analytical record may be necessary for adequate learning feedback. Complete records of trainee gunnery attacks may provide data relating to each other error in azimuth, elevation, ranging and triggering.

The limitation of such records for learning purposes is that they are presented too long after the trainee has made the responses. Another disadvantage is that the response pattern is not readily related to a stimulus pattern to the trainee in such a way that he can use the recorded data for habit correction. (Pages 64-66.)

Ideally, the record should (1) be flashed back to the trainee immediately after the response cycle (such as an attack); (2) show the stimulus as well as the response track with time indications which permit matching them; and (3) such stimulus cues as will permit the trainee to get prepared to avoid some particular error when that practice cycle is repeated. (Phosphorescence might be a suggested solution for parts one and two of this problem.)

3. Showing relations of one part of performance to another: The memory system intrinsic to recording systems may be used to show the trainee how inadequacies of response in one phase of a job segment were reflected in an inadequacy in another job segment. Thus he may see from a navigational record of his flight path why he failed to rendezvous at the proper time and place, or why his bomb missed the target. Loosely speaking, recorded data may help the trainee learn the "tactics" of his job. The memory of the trainee and instructor both may be inadequate or unconvincing for such a purpose.

4. Aiding the overloaded instructor: The instructor in modern training devices is often heavily loaded both in sensory and motor demands. An automatic recording system may reduce this load. It may not always be necessary for the recorder to run continuously; sometimes it may be sufficient to sense and store data for no more than a few critical seconds. If its continuous operation requires heavy monitoring from the instructor, it may be as great a liability as an asset -- or more so.

> For example, the instructor in a fighter gunnery trainer may need to 'fly' the target and monitor flight instruments slaved to the trainee's instruments. A graphic recording of the flight track would provide the instructor a record on the adequacy of flight technique, a record of value which could not be captured on a memory basis by the instructor. Track made good during entrance into the attack course and during pullout is critical. On the other hand, a continuous record from beginning to end of right-left, forward-back 'stick' movement would become meaningless detail.

Recording may be desirable both for information which flows very rapidly according to human capacities to receive it (such as a gunnery pass) and for information which flows very slowly (such as in some navigational practice sessions.) The procedures which provide scoring variables and scoring equipment may, by logical extension, help determine what, if any, recording equipment may be desirable for the instructor's station.

SPECIAL RECOMMENDATIONS

> If the recording method produces a graphic record, provisions may be made for the instructor to scribble notations or symbols which will help him in later recall when he reviews the trainee's performance. It should be easy for the instructor to add such notations. Even if it is impracticable for him to be able to write on the tape, some signal marker might be provided for him to use with a switch. This signal marker would show on the tape the point at which the instructor had a comment to make, and thus help remind him of the comment.

Important Considerations In Design Of Recording Equipment For Teaching

Preliminary thought to the addition of recording equipment to the training device should be subjected to a number of realistic questions. The answers to these questions may lead to revision or abandonment of recording for training purposes; although it may be possible that the equipment might be retained for evaluational purposes alone.

1. What demonstrable contribution does a record have in this particular training problem over transient presentations of information (that is, information which is erased by or pooled with the next response the trainee makes)? By precisely what steps will the instructor (or trainee) transform the recorded data into better task performance? Why could not precisely the same objective be reached with greater flexibility without the record?

2. How much time is required of the instructor to decode or decipher the recorded data into information which the trainee can use to guide his specific behaviors in the task?

3. How much attention is required of the instructor to monitor the recording equipment? Might not this attention better be directed towards transient scores or by watching directly the trainee's performance?

4. Does the record permit accurate matching of input and output to and from the trainee? That is, can the instructor help the trainee match his response error with the inciting stimulus so that the trainee may get a mental "picture" of how and when to make proper response corrections over his previous performance? How reliably does the scoring arrangement perform insofar as matching inputs and outputs of trainees?

5. Does the record permit direct, unambiguous comparison of what the trainee should do and what he does do?

6. For how many phases of learning intended for training on the trainer is the form of recording appropriate? Thus an elaborate recording arrangement may be useful for no more than a brief portion of the training problem. If behaviors in this portion of training are critical to later job performance, or are made more difficult to learn without scoring records, the recording equipment may be justified, in spite of the limited time during which it is used.

7. Is the scoring mechanism dependable in operation? Can difficulties (such as failure of pen or stylus to write) be corrected in a few seconds, or are standby mechanism provided for immediately taking over an impaired function?

8. What provisions for stand by scoring are available to the instructor if the recording equipment goes out? Some training devices have been so designed that they are completely useless for training if the recording equipment fails. The instructor should have alternate modes of getting at least partially adequate data for training purposes while the recording equipment is under maintenance or repair.

9. What provisions are made for simple calibration and adjustment?

Recording For Evaluational Purposes[1]

The assessment of either relative or absolute proficiency places a premium on objectivity and reliability of performance measurement. Objectivity implies freedom from personal or other bias introduced into measurement by an observer or handler of the performance data. Reliability refers to the extent that conditions which produced measurement at time A are reproducible in a measurement to be made at time B.

Theoretically, scoring and recording should be just as objective in training as in evaluating. Practically, however, the interactions with the instructor characteristic of training permit ironing out of some unreliability, especially over a number of practice trials. But evaluation is more or less a one-shot affair in which unreliability in observation or recall by the instructor lacks opportunity for correction. Hence it becomes important to relieve the instructor as much as is practicable of matters involving attention and adjustment in evaluation and proficiency testing.

The problem of relating stimulus to response is not crucial in records used for proficiency evaluation, as it is for training purposes. In general, the question asked of the data is, "Did the trainee fulfill the requirements (of the job, or of training as the case may be) or did he not?" For strictly administrative purposes it may sometimes be helpful to know which requirements were or were not fulfilled; but for training purposes it would be absolutely essential to know.

Summary of Recording Methods And Types of Devices

Any recording device will include the following features:

1. A data pickup or sensing member. This member may be coupled either directly to the control activated by the person trained or tested, or it may be coupled to some machine output linked to the control activated by that person.

2. A signal amplifier or encoder. This mechanism translates the picked up signal into values or units which are comparable from one sample performance to another.

3. The inscriber. This is the instrument which leaves a track or index marking on some permanent or semi-permanent material.

1. Discussion related to Recording for Evaluation can be found in Chapter VI, Proficiency Measurement.

4. The record. The material upon which the translated job operation is fixed as a datum.

Note that any one or a combination of these four items can be performed by a human observer with a lead pencil and a piece of paper.

The classification of recording devices may be according to some one or more of these portions of the recording system. Thus, optical recorders are identified by their method of picking up and "inscribing" data -- presuming the datum consists of light rays impressed on a photographic emulsion. The following list is not exhaustive; nor does each item include all four factors of sensing mechanism, recording and transmission mechanism, inscribing procedure and record material. The list is intended to be suggestive of record-making possibilities.

1. Instructor makes notes on paper.

2. Instructor makes notes on a check-list. This procedure is somewhat more objective than 1.

3. Instructor speaks into a tape-recorder. He may be guided by a check-list. Or instructor may activate switches which put code marks on a moving-drum recorder.

4. Continuous time accumulators are photographed, or instructor takes record by hand. Examples of time accumulators are chronoscopes, Standard Electric Timers.

5. Counters with data photographed or impressed on tape at given intervals. Counters will accumulate any discrete units, including time marked into pulses.

6. Moving drum recorders (kymograph type). A continuous strip moves at constant speed past one or more recording styli. The stylus may write with ink; a thermoelectric contact may burn the paper; or mechanical pressure of the stylus may trace lines on a waxed surface.

7. Moving crab recorders. These are a variation of 6, except that the record bed remains stationary and the writing platform moves in two coordinates guided by a selsyn system. Time can be indicated by a special periodic pulse delivered to the recording pen or tracer.

8. Optical pick-ups transform light into a photographic record either on stationary emulsion, continuously moving paper or film, or in discrete, successive frames.

9. Phosphorescence could be utilized to record, at least during a brief period, the track of special light beams (infra-red).

10. Card punches (international Business Machine type) can record many categories of simultaneous discrete data.

Mechanical Properties of Recording Mechanisms: Design Considerations

It may be only partly oppropriate to point out several important engineering considerations in the design of recording equipment. Since these considerations will be generally well known to engineers, it may suffice merely to mention them.

1. Sensitivity: How small a human response is matched by a correlated reponse in the record, appropriate in direction, magnitude and time? The required limits of sensitivity for recording can be determined on the same basis as are the required limits in scoring.

a. In general, they should be based on the limits of what the highly skilled operator himself can or need do nothing about by way of correction either as "action feedback" or "learning feedback."

b. The second appeal should be to systems outputs. Sensitivity in recording need be no greater than to differentiate tolerance from non-tolerance performance when recording is used for proficiency measurement. This statement assumes use of an "absolute criterion." A good general rule, in any event, is that recording of response (in magnitude or in kind) which makes no difference to the system output is unnecessary.

c. If recording is to be used for research purposes not directly connected with training or proficiency evaluation, these purposes will have to dictate the degree of sensitivity required of the recording mechanism.

2. Recording range: Recording range should be based upon the purposes intended for recording. If the record is to be used for training, the range should extend somewhat beyond the poorest and best performances when the trainee is subjected respectively to the most difficult and the least difficult "programs" or exercises.

If the record is to be used for evaluation, the necessary range will depend on the method of evaluation, whether it will be pass-fail with respect to an absolute criterion of performance or on trainee-trainee comparisons and norms. If the former, the range need not extend far beyond the tolerance limits established for criterion performance. If evaluation is to be based on group norms (which it usually is) then recording range will have to be based on empirical data which show dispersion (standard deviation) of sample testees on the given task. If the sample of testees is representative of the population to be tested, three standard deviations on each side of the mean shold provide a range more than adequate for all practical purposes. This range would accurately locate, with respect to relative position in performance, all but 0.3 per cent of the popul tion to be tested.

3. Backlash on training or performance of Tasks: Performance on the operational or training task should be unaffected by the process of recording. That is, recording should not introduce artifacts into either the displays or control systems in the testee's work situation. The substitution of optical and electronic methods for mechanical methods of data pick-up has reduced the problem of backlash on equipment linkages.

Recording may introduce another kind of backlash, however. Thus, the instructor may have to require the trainee to make artificial pauses mid-task in order to readjust the recording mechanism, or change a tape. Or sounds and other cues may provide spurious information to the trainee or person tested.

4. Reliability of Recording: The validity of any score is almost inevitably attentuated by unreliability introduced through scoring and recording of performance data. The practical meaning of this unreliability is that testees will be passed who would (and should) have been failed, and some testees will be failed who should have been passed.

It may be desirable to provide some standard inputs by which to test the reliability of the scoring and recording mechanisms. These inputs should sample from the range of programs and response outputs of the tasks on which behavioral outputs are being measured. The test output on the record should be readily comparable with the standard input to the scoring or recording mechanism.

5. Validity of Recording: If on the operational device the trainee would be "on-target," does the record on the synthetic device indicate "on-target" or vice versa? It is understandable that there will be some intrinsic machine error in the recording system. But this error should be random with respect to the outputs of trainees rather than systematic and thus biasing. (Random error in the recording system is a matter of unreliability rather than of validity.)

It is also highly important that the recording system be valid for all portions of the scoring range or segments of a behavior path.

Instructor monitoring of recording equipment: A recording mechanism adds to the task of the instructor. It should be designed with the recognition of this fact in mind. Its operation should be readily monitored and controlled as a part of the rest of the instructor's duties, especially if time-sharing in other tasks is involved. This matter is also referred to in the chapter dealing with the instructor's station.

CHAPTER VI. PROFICIENCY MEASUREMENT

The primary purpose of proficiency evaluation always is some kind of administrative decision. Thus "Which of these trainees are fit for the job and which are not?" or "Which men are deserving of a promotion?" or "Which men should be returned to training?"

Job proficiency is determined with perfect reliability and validity only by evaluating all that a man does during his lifetime on or at the job itself. Any other "test" of proficiency is an attempt by economical means to select a sample from the universe of job problems he is going to face, and make this sample as representative as the purpose of proficiency evaluation and the budget of time and money permit. Other things being equal, the wider the range and the greater the number of job relevant programs (or test items) presented to the tester, the better our prediction, but with somewhat diminished returns. Evaluation is not an end in itself: it is meaningful when it predicts future job performance.

Absolute vs. Relative Criterion

There are two main approaches to the evaluation of proficiency. An example dealing with hardware rather than personnel may highlight the difference.

A customer goes into a store to purchase a calibre .30 rifle. He states that it must fire with a two mil gun error or less. The shopkeeper needs do no more than clamp the guns in his stock into the right kind of vise, sight the gun and fire a number of shots. He can then put those which conform to the criterion on one pile, and those which do not in another pile. Presumably the customer will now accept any rifle in the first pile, unless he brings additional criteria to bear.

This is a go/no-go or pass-fail criterion against which to determine proficiency or acceptance of a product. It is clean cut, but depends on the customer knowing what he wants or needs. Operations analysis or its equivalent may help to define human ability requirements in about the same way.

But consider another situation. The customer says, "I want the five most accurate calibre .30 rifles you have in stock". After testing the inventory of rifles, none of us knows if any of the rifles is good enough, or if on the other hand the customer is getting rifles far more accurate than he needs or should have to pay for.

Or the customer may ask for a rifle with a two mil error or less, and no rifle may meet these specifications. Under these circumstances the customer may legitimately ask for the five rifles which most nearly meet his need. In both of these latter cases the customer was accepting a criterion based on supply rather than demand; and a comparative (group norm) rather than absolute criterion.

In most practical cases in hardware and in human ability requirements, there tends to be some compromise between the pass-fail kind of criterion and the group-norm kind of criterion.

The Criterion For The Job

Proficiency measurement is meaningless unless some kind of criterion is specified, and some method of acceptance and rejection made explicit whether it be on the basis of norms, proportion of available groups, or absolute quality standards. Obviously, the higher and more rigid the quality standards, the less guarantee of sufficient quantity, and vice versa. But whether persons be selected on the basis of absolute criteria or on the basis of group norms, proficiency measurement should be established from the variables found in the job requirements.

It is sometimes necessary to use the same method of measurement for determining not only pass-fail groups, but for dividing a test group into a larger number of sub-groups. Thus we might want to separate a total class of trainees into (a) those proficient enough for operations, (b) those not proficient enough for operations but worthy of more training, and (c) those who are to be washed out of training. Additional sub-groups could be defined, such as those who are to be transferred to a related but less difficult job or training task, and so forth. Ideally, there would be objective criteria for acceptance into each of these groups, and these criteria would be set up in advance and independent of relative performance on the evaluation test. This ideal is usually unrealistic because such independent criteria are rarely available. Instead, the practice is to measure or rate performance of the group members on the evaluation test, then put the top 100 men into operations (if you need 100 men for operations) take the next lower 25 men and put them back into training (if you have room for the 25 men in training) and wash out the bottom 25 men on "general principles" or because you don't know what else to do with them. This procedure has the merit of simplicity in that it avoids the difficult problem of determining exactly what performance defines success in operations, or defines the need for retraining, or defines non-worthwhileness for additional training.

In any event, the engineer who is faced with the problem of designing a device to test or evaluate proficiency should attempt to get the user of the device to specify the following:

1. Will an absolute or relative criterion be used in determining what will happen to those tested?

2. If an absolute criterion is to be used, what are the precise performance requirements (stated in behavioral operations) which distinguish pass-fail boundaries? This information is essential to efficient designing of scoring and recording equipment, and to the selection of test "programs" of problems.

3. If pass-fail criteria are not available or planned, what basis will be used for dividing those tested into various proficiency groups or levels?

Many other considerations go into the design of proficiency measuring devices. For example, are some job outputs or consequences more important than others? If so what are they, and what shall be their relative weights in the total score or decision to be made about the trainee? To what extent should the variables and test items have reference to selection tests given to the trainees when they entered training? These and other research questions are important to resolve before undertaking the development of proficiency measuring devices. Although they are outside the scope of the design engineer, the answer may have considerable bearing on the kind of equipment which is built, especially with respect to scoring provisions, organization and programming of test content, and the provision of alternative forms of the test.

Notice that the approach described thus far emphasizes the critical aspects of job outputs determined by analysis of what the man-machine system has to do. The logical validity of this procedure seems clear. There is another approach, however, in which an attempt is made to reproduce the physical conditions of job operations in a synthetic device and from this synthetic model of operations derive criteria of job success. Physical fidelity, without consideration of how much or what kind may be necessary, is used in the attempt to guarantee psychological fidelity. The designers hope that through a thorough copy of the job itself (except that inputs and machine outputs are synthetic) the pattern of job success will reveal itself.

This shotgun approach has the following difficulties:

1. Physical simulation is always a matter of degree in kind and scope of what is reproduced.

2. The selection of "programs" may weight variables and behaviors beyond their importance in actual operations.

3. Programs may not include testing the full range of the trainee's ability, especially under various kinds of load which may arise in operations.

4. Thorough physical simulation of operational conditions is extremely costly, especially without a guide as to what corners can and cannot be cut.

5. The inclusion of scored items which are non-diagnostic of success or failure in operations reduces the reliability of the overall proficiency evaluation in predicting criterion performance in operations.

Deciding What To Include In The Evaluator

The same general considerations which go into the decisions of what to include in a trainer also go into the decisions of what to include in an evaluator. These considerations are summarized below.

Let us presume that a complete behavioral task analysis has been made of the operational job (or group of related jobs if a team is to be evaluated). The following steps should be taken in designing the evaluator:

1. Selection of tasks: The first step is to decide how many and which ones of the operational tasks shall be included in the device.

Some groups of tasks may be tested in separate devices, although the selection of these groups should be based on considerations discussed above under part-task trainers. (See Chapter III.)

Thus, if tasks are time-shared it is usually risky from the standpoint of validity to test them outside the time-shared context. It may be as important to note what behaviors or task performance will not be tested by a given device as what will be tested. In this way other provisions may be made for evaluation of performance on the other tasks or job segments.

2. Selection of sample programs: It is essential that the programs or problems actually presented to the testee be at least representative and, if possible, exhaustive of the kinds of critical situation with which he will have to cope.

Any evaluation must be based on some sample of the total job situations which the operator will encounter. Thus, to give a final evaluation of a gunner on the basis of one shot at a single kind of target would not allow us to predict how well he would do on different kinds of targets (to say nothing of how reliable he would be in hitting the same target on another try).

> Program analysis needs therefore to have been made of the operational job; in fact this analysis should have been part of the task analysis.

a. Programs should be varied in difficulty as well as in kind and in combination.

Other things (such as degree of learning) being equal, the greater the number of things the operator must perceive and do at about the same time, the more difficult the task; the more information he has to carry in his head at about the same time in immediate job performance, the more difficult the task; the less that standard routines which he has learned enable him to cope with a job problem, the more difficult the task.

b. Some programs should be included as test items which go considerably above expected operational demands in order to explore the upper limits of the operator's capabilities, especially where operational pass-fail criteria are not established.

c. Eliminate non-diagnostic material from test "programs".

Because testing time is usually very costly, the planning of programs to put into the evaluating device is important not only from the standpoint of validity of testing, but also in economy of testing. Customarily an 18 hour operational flight has many relatively "dead spaces" of little or no job activities. It would probably be uneconomical to simulate such dead spaces in 18 hour flights; in this respect the copying of actual job situations would not be efficient testing procedure. We should remember that we want to confine testing to those requirements of the job which do differentiate superior from inferior performers. If sustained vigilance or resistance to fatigue effects were included as critical job requirements, however, testing might require 18 hour sessions with "dead spaces."

d. Provide test material that is highly reproducible and standardized from one test to the next.

Unlike the demands of training, proficiency evaluators must have highly reproducible programs so that each person tested is exposed to the same standard conditions or inputs. Such standardization may require that a good deal of the programming of inputs to the testee be automatic rather than left to the option or manipulation of the instructor.

e. Provide alternative standardized programs for testing.

Standardization of testing conditions introduces another problem which must be met. After trainees have taken tests, word gets around that "an engine fire in number three occurs right after take-off" so that persons tested later have special advantages. Evaluation tests must therefore have alternative forms of equivalent difficulty. The equivalence of tests can finally be determined only by empirical methods of actually testing matched groups of trainees on the variations of the test and making statistical comparisons.

If the test has comprehensive coverage of the job requirements, the "word that gets around" can merely be that the test covers all of training. Trainees can get advantage only through knowing in advance what sequence of items will appear. If this is true, the only problem is to rearrange the sequence of test items in alternative forms of the examination. Care must be taken that one sequence of items does not present greater difficulty than alternative sequences.

But where content of programs (such as in navigation) can be changed, such changes should be made.

f. Pre-test all materials on a "pilot" group of trainees and graduates.

In any event, it is essential that pre-testing be made of the equivalence of forms of the test before the test is given full-scale use in predicting operational job proficiency. Specialists in test and research design can aid in making the test economical and efficient.

What variables to score: The proficiency evaluator, strictly speaking, should produce information about the trainee's getting jobs done. As such, we are not concerned about giving the trainee useful information for purposes of learning; we are concerned primarily with deciding whether or not to let him undertake the real job; or what kind or level of responsibilities to assign to him in operations.

Consequently our interest is primarily directed not to the responses the trainee makes as such, but to whether or not the responses he feeds into the machine produce the requisite man-machine output. Do the bullets or bombs hit the target within a given acceptable ratio or degree? Does he land the airplane without crashing? Does the airplane follow an efficient navigational course? Does the propeller get feathered before runaway and without damage to the engine? Is the enemy intercepted at the proper time and place? [1]

Notice that these questions are about primary mission objectives. Secondary objectives may be derived from the primary objectives. For example, a pilot may perform a series of maneuvers very successfully, but jam his throttle from one position to another so as to cause unnecessary wear on the engine, or be wasteful of fuel, [2] or risk killing the engine. In cases such as these, the response itself might more economically be noted and scored directly, rather than by effect (or hypothetical effect) on a machine. But proficiency data obtained in this way are bound to be more subjective and may sometimes unduly bias the final evaluation. Finally the score must yield

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[1] Ideally, these determinations would have been made of the trainee's performance with the "elimination" of machine error. (See p. 96 below)

[2] Perhaps the concept of "amount of waste produced by response" should be made one of the explicit criteria of job performance and recognized as such in the task analysis. Any analysis of a complex system's efficiency is related to a ratio of productive output to waste, and the same approach might be taken more explicitly to the evaluation of human performance.

the basis for making a yes or no response to the question: "Shall the man be assigned to operations or not?" -- or to some similar type question calling for a material decision.

The quality standards and quality variables of any man-machine system generally are peculiar to that system and thus specific prescriptions of these variables cannot be made to cover a variety of jobs and systems. The quality variables of a lathe-produced product are peculiar to the needs which that product must serve; thus one must turn to the needs rather than the product itself for standards of acceptability.

Recommendation in determining the variables to score: The designer of the evaluator should attempt to determine those fewest variables of machine output which are common to all or the greatest number of programs and problems to which the man-machine will be subjected and which determine adequacy or inadequacy of overall performance. From these few variables refinements may be determined. The designer should ask the question, "What does information about this variable tell us with respect to our decision about accepting or rejecting the testee which is not already summarized in more general variables?" Such questions may help in not letting the scoring problem get out of hand. Scoring must never become an end in itself.

Proficiency evaluation and selection testing: Proficiency evaluation may sometimes have to aid in justifying or modifying selection testing programs. If this is true, new families of problems and considerations may enter the picture. It is important to keep selection test validation and research problems separate from those connected with decisions about the fate of those tested. The use of proficiency tests as tools for research is outside the scope of this discussion, and likely to be outside the immediate responsibility of the equipment designer except insofar as design requirements are already imposed on him through external channels.

Scoring And Reference Baselines

The interpretation of scores may be greatly helped by automatic reference indications telling the evaluator when the performance of the man-guided machine is within tolerance limits and when it is not.

Such references not only simplify the chore of interpreting scores, but increase the reliability of the evaluating process. If practicable, the tolerance reference should be subject to change by the evaluating agency in the event that there is need to tighten or loosen the tolerance. If it is not practicable to make a variable tolerance indicator, then it should be possible readily to remove the fixed tolerance indication from the record or other display. Thus the interpreter of the record (or other scoring display) will not be confused by the presence of reference marking when it is inappropriate.

Excluding Machine Error From Scoring In Evaluation

If the purpose of an evaluation procedure or device is to measure the effectiveness of a man-machine team as such, the operational error (or unreliability) of the operational machine would need to be simulated.

But in evaluating the proficiency of the operator or trainee as such, the evaluation is merely made more unreliable by confounding the machine variable error with human error.

That is to say, the aim of proficiency evaluation is to get as reliable an index of the performance of the man as is practicable on a small sample of trials. Assume that when man X tries a gunnery pass, the machine's error is large, but when Y tries a pass the machine error just happens to be small. If the score includes machine variable error, our evaluation of X with respect to Y will be biased.

Even when we are concerned with an absolute job criterion, the absolute criterion of human performance should, if possible, be determined in such a way that machine variable error, as it affects a job output, has been eliminated. (By definition, machine variable error is error about which the operator can do nothing!) By adding it to a test of the man, any individual measurement about the man's performance has its reliability diluted.

If, however, the unreliability of the machine is a factor with which it is part of the man's job to cope (such as in maintenance operations) and he can make or learn to make responses which do cope with it, then that type of unreliability should be represented as part of the "programs" which test his job proficiency.

Problems of measurement can be unravelled only if it is clearly recognized and decided exactly what the measurement is to be about (the man, the machine, the man-machine team, and so forth) and then to remain consistent with that decision.

Measuring And Evaluating Human Reliability

It is often important to know not only a person's average performance on the job, but how reliable -- or how variable -- is his job performance from one assignment or mission to the next.

In order to know the reliability of a man's skill it is necessary to get repeated measurements of his performance on equivalent samples of task programs or problems. If the same problem is given to him more than once, there is the likelihood that some specific learning effects will have occurred. These effects would contaminate our estimate of his reliability on the job where programs are not likely to be exactly repeated, or if they are, the repetitions are interspersed with different programs.

By getting scores on a number of equivalent items (or programs) not only can the mean of scores be obtained, but a measure of dispersion such as the standard deviation can be obtained for the individual. (It is, of course, common practice to get both average and dispersion scores for groups of individuals in the computation of norms.)

For example, we may find that the average circular error of two bombardiers is 100 feet. But the first man's drops cluster within 200 feet of the target, and although more of the second man's drops are bull's-eye hits, he also occasionally misses by 1000 feet. The second man would be a better bet to bomb the enemy troops when they were far from friendly troops, but a poorer bet if the enemy had to be bombed when only 500 feet from friendly troops.

If the reliability of the individual's skill is to be determined, variations of the same item must be programmed in the evaluation procedure. Provision must also be made for scoring and combining scores into standard deviations or other measures of dispersion. Reliability of performance could not be obtained from a counter which kept only an accumulated average of performance on individual test items, or otherwise pooled scores.

CHAPTER VII. THE DESIGN OF THE INSTRUCTOR'S STATION[1,2]

Introduction

Designing the trainee's station is devising equipment for helping someone to learn to operate other equipment. But the design of the instructor's station is devising the work space and equipment itself for an operator. Thus it involves many of the same human engineering principles which apply to the design of an airplane cockpit or radar operator's panel. There are some special problems, however, to which specific attention may be directed.

First, let us enumerate the general requirements or functions of instruction and the instructor:

1. Motivate trainees to practice and learn.
2. Provide guiding information, principles, and ideas about doing the job.
3. Demonstrate criterion performance if necessary.
4. Provide, control, and monitor the stimulus inputs (programs and problems) to the trainee.
5. Notice the trainee's output and compare it with criterion performance such as in scoring.
6. Provide and help interpret knowledge of results to the trainee.
7. Direct trainee's attention to critical inputs and outputs at various times.
8. Control general conditions of practice (such as how much, when, and at what intervals; adjusting degree of task difficulty; integration of part skills; integration of training into operations).

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1. This chapter is a summary of the report by Swain, Alan D. Guide for the Design and Evaluation of the Instructor's Station in Training Equipment. Wright Air Development Center Technical Report 54-564. In many places direct quotations have been made. For a complete checklist and set of recommendations, the reader should consult this reference.

2. Because there is little discursive comment or "theory" in this and the following chapters, special signals denoting Trainer Recommendations seem unnecessary and are therefore omitted.

9. Evaluating trainee performance with respect to other trainees or an operational criterion.

10. Effecting transition from instructor dependence to self-dependence.

11. Operating the mechanisms of instruction.

At least indirectly, all of these functions are reflected in the design requirements of the instructor's station.

The block diagram on the next page schematizes many of the functions and their relationships as outlined above.

GENERAL LAYOUT OF THE INSTRUCTOR'S STATION

Every layout will be a compromise between sets of advantages and disadvantages. The following suggestions are intended as guidance.

If the trainee is in early stages of learning a complex perceptual-motor and decision-making skill, it will generally be desirable for the instructor to be close to the trainee and watch him directly. Thus he can guide, offer directions when the trainee's memory falters, instill or correct scanning habits and eliminate not only gross errors but error tendencies through direct observation and communication. In later and high degrees of learning a skill, less may be lost and more gained if the instructor is more remote, and receives and transmits information through instruments.

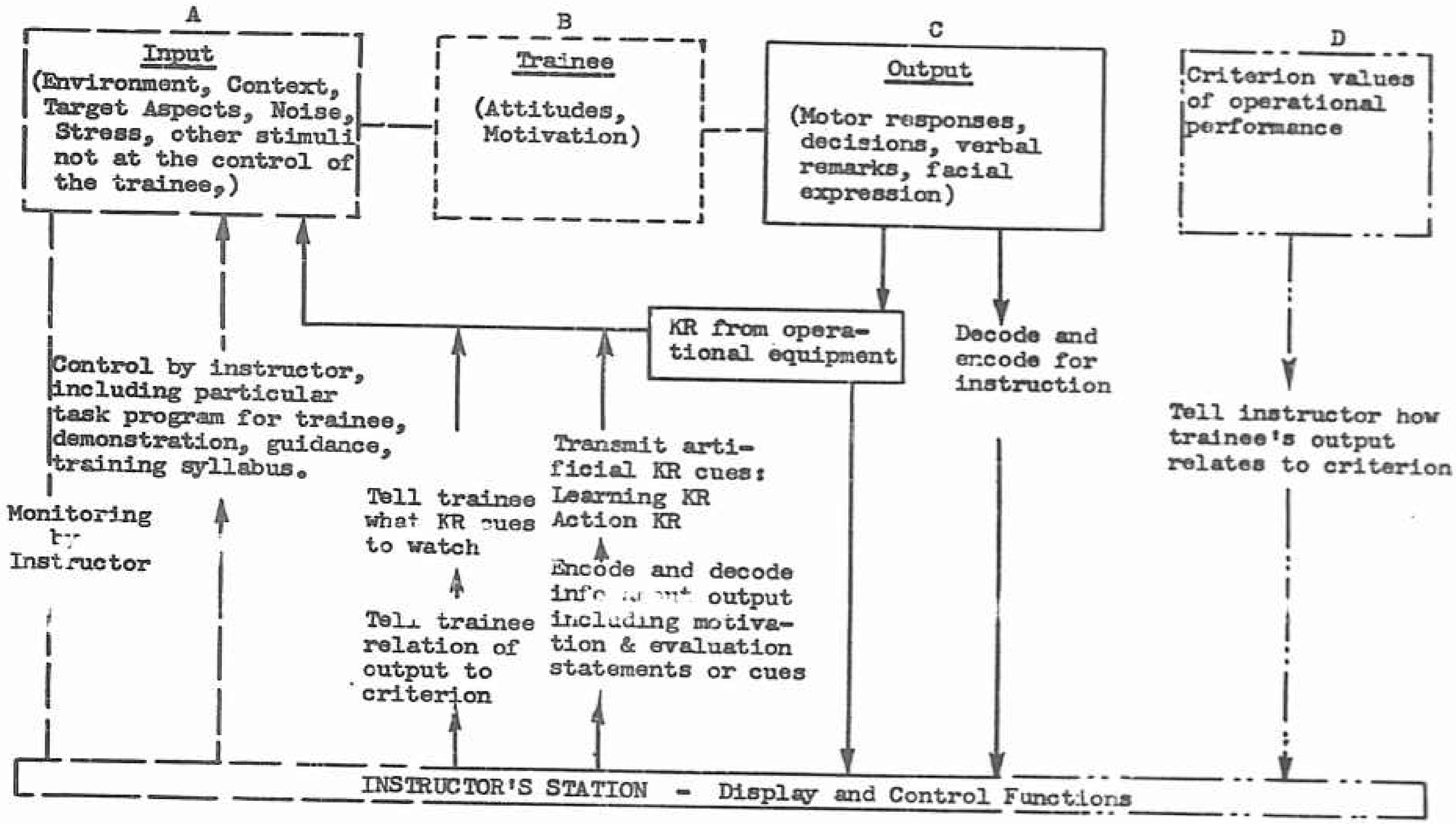
Transition training provides a special case where large amounts of confusion and negative transfer may be experienced by the skilled operator of one device who is being transitioned to a similar device. For transition training, close physical proximity of instructor and trainee is desirable.

If the expected level of teaching skill and experience of the instructor is low, more instrumental aids will need to be built into his station than if he is highly skilled and experienced.

And if the instructor on the training device also must maintain skill on the operational device, precautions must be taken so that his operating the trainer does not degrade his skills in operations. This problem can easily be exaggerated, however, because it is relatively easy to learn separate habit systems if the various contexts in which they occur are markedly different.

General Equipment Considerations

The trainee should not be able to see the instructor's panel, nor see (or hear) the instructor's movements in controlling the panel. On the other hand, Trainee's Feedback Loop as it is Monitored and Controlled by Instructor's Station. (Note: Monitoring and control may be vocal or mechanical. KR is short for Knowledge of Results or Feedback.)



the placement of the instructor's station should not interfere with the discriminations, decisions and motor responses required of the trainee for training purposes. Instruments and controls most used by the instructor should be within his frontal visual field and within easy reach. However, where the layout is complex and the instructor has time-shared activities, displays and controls should be grouped on different panels accordingly.

The instructor should be able to see as much of the trainee's work-space as is consistent with other considerations. At least, without too great inconvenience, he should be able to move into a position from which he may observe both trainee and work-space.

Symmetry should never be used as a principle of design until all human engineering considerations have been taken into account

Location Of Instructor Relative To Trainee

The discussion above has already emphasized when it is desirable to have the instructor close to the trainee. It is probably a good general principle (unless one has poor instructors) to get as direct interaction as possible between instructor and trainee, unless the instructor provides too much artificial information, or is likely to misinterpret the trainee's performance, or what is important in the trainee's behavior.

Some training devices may provide a number of alternatives. The instructor may sit so as to observe the trainee directly, or monitor the trainee's outputs from a shielded booth; or a combination of direct and indirect contact may be designed. This will, of course, depend upon the nature of tasks being trained in the trainer. For example, in a visual reconnaissance trainer the instructor's location might be such as to permit him to observe the trainee directly and to observe the trainee's instrument panel and the target (trainer) presentation. Here the required learning is primarily perceptual.

OPERABILITY OF THE TRAINING DEVICE

The training device should be designed so that the instructor can pay maximum attention to the job of instructing and minimum attention and effort to monitoring and activating the device as such. In case of complex trainers it might be most economical to have trained technicians warm-up, check, and maintain the device, thus leaving the instructor free to devote full attention to the trainee.

Checks For Operability; Warm-Up Procedures

Determining whether the trainer is operating within tolerances should be simple, rapid and thorough. Simplicity of calibration and adjustment will tend to guarantee that the device will be correctly calibrated and adjusted. Fuses and lights should permit ready access and easy replacement.

Warm-up procedures should be simple. There should be automatic provision against damage to the equipment by incorrect warm-up procedures. Indications that the equipment is ready for use should be clear and unambiguous, although not necessarily centrally located.

Indications of on-off status should be clearly visible to the instructor. So also should be a master indicator of the over-all operative or inoperative status of the equipment.

SCORING AND RECORDING EQUIPMENT

Problems in this area have been treated in Chapters IV, V, and VI so they will not be restated. It may be emphasized, however, that the arrangement of scoring and recording equipment should take into account the time-sharing activities of the instructor, and his problems of interpreting several channels of information at about the same time. Scoring displays which should be read at or about the same time should be grouped in physical proximity. Scoring displays presenting information which needs to be integrated by the instructor should either be grouped in physical proximity, or distinguished in some way (as by color) so as to aid in a grouping effect.

The presence of scoring and recording equipment which is not used acts as visual noise to the instructor.

DISPLAY OF TRAINEE'S PERFORMANCE TO INSTRUCTOR

This section deals less with *what* to display at the instructor's station than *how* to display it. Because the topic of display design is treated more fully elsewhere,[1] only a summary treatment is offered here.

Perceptual Simplicity

The way in which channels of information are arranged in a work-space makes for relative ease or difficulty in perception and use.

The first principle is *visual accessibility*. All displays to be monitored by the instructor should be visible and readable from his position with the

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1. Baker, C. A. and Grether, W. F. Visual presentation of information. WADC TR 54-160, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio.

possible exception of those connected with turn-on and turn-off procedures. The display face should be tilted so that the information can be read from the normal sitting or standing position of the instructor.

The grouping of displays may be organized around one or more of the following considerations:

Joint monitoring of trainee's and instructor's station: Does the location of the most frequently used instruments on the instructor's panel facilitate division of attention between displays in his own station and displays in the trainee's station?

Functional grouping: Instruments may be grouped on the basis of spatial location or by coding them by color, size or shape. The basis of grouping may be time-sharing or reading, or they may be grouped according to trainee outputs or equipment outputs which logically are associated with each other.

Sequential grouping: Displays may be laid out to follow the sequence or pattern of operations required of the instructor. Thus if the instructor frequently has to read several displays in a fixed order, they could be laid out in a straight line and according to the sequence read. Because of the relatively few such standard sequences, and also because of space limitations, sequential grouping may not often be feasible.

Grouping by isolation: A group of displays can be perceptually "isolated" by enclosing it with a white line on the panel, or by using fields of different colors as background. More than a very few such groupings in the same workspace, however, may create more confusion and visual noise than aid.

Operational meaning: If the instructor also operates the operational equipment, operational displays should be spatially related to each other so as not to interfere with his normal scanning and perceptual habits. Scale may be reduced, but relative position should not be changed.

Type of display: The same frame of interpretive reference should be used as much as possible for all displays. This applies to the units used, the direction in which the pointer moves, moving scales vs. moving pointers, and so on.

Legibility Of Displays

A number of items should appear on any human engineering checklist for displays with respect to legibility. These items include: (a) Identifiability of the display; (2) Size of display relative to distance viewed; (3) Illumination; (4) Numerals and letters; (5) Pointer design; and (6) Scale design.

Other Display Considerations

Some forms of display movement are more easily read than others. The more easily read are those conforming to populational stereotypes (clockwise movement of pointer to indicate increase, upward motion of pointer indicating increase in magnitude, and so forth). Where a conflict of such stereotypes exists in a display problem, some alternative solution may be sought if time is not available for study of the problem.

Repeater displays at the instructor's station are especially desirable when the instructor on the training device is also an operator of the operational equipment. Repeater displays are usually less expensive to install than displays which, while showing the necessary information about the inputs to the trainee, are specially designed to present the data more simply to the instructor. Repeater displays are also desirable when the instructor is required to determine what stimulus (or noise) areas the trainee is responding to, or should respond to, in a display which is otherwise inaccessible to the instructor. For example, a radar scope at the instructor's station which is slaved to the radar observer trainee's scope will permit the instructor to observe the trainee's tracking responses during fix taking, bomb runs and wind determinations. This will enable the instructor to forestall the development or reinforcement of habits involving marked perceptual and motor response errors. (In this case the "operator" is not the operator of the equipment). But before it is decided to use repeater displays, the possibilities of complete revamping of the displays to the instructor through alternative design should be explored. Any radical simplification would likely pay off, especially if the instructor will be teaching on the device for some time.

In general, if the instructor is also an operator of the operational equipment, rather than introduce minor changes in the control-display configuration and relationships, it may be better to undertake major re-design to emphasize to the instructor differences in training and operations contexts and thus reduce habit interference.

Reduced delay between trainee's output and data to instructor:

In teaching of tasks in which there is appreciable time lag (more than three or four seconds) between the trainee's response and a normal feedback, it is especially desirable for the instructor to get immediate data about the trainee's response ahead of the normal feedback. This elimination of time lag obviously occurs when the instructor is able directly to watch the trainee at work, as well as observe the displays and the instrumental feedback. The instructor can then provide supplemental feedback or guidance more synchronous with the inadequate response, and thus facilitate the elimination of the incorrect response.

THE INSTRUCTOR'S CONTROLS

Considerations about controls will tend to parallel many of those under displays. As in that section, treatment here will be summary because of the material on the design of control systems which is available in the controls section of the Joint Services Human Engineering Guide to Equipment Design. (in preparation.)[1]

Accessibility and location should be based on frequency of uses; avoiding the likelihood of inadvertant manipulations; and avoiding the need for the operator's hands to cross while manipulating more than one control at a time.

As in displays, controls can be grouped according to function or to sequence of use, or controls can be isolated (as by border or common color, or operational meaning). Unless there are opposing reasons, population stereotypes of control movement (for example, turn clockwise to increase magnitude on a moving-indicator fixed-scale display) should be incorporated. Reduction of errors is likely if all control-display relationships are in the same direction, unless conflicts with previous habit patterns of the instructor will arise.

Controls should be placed close to their related displays, and usually directly under the display.

Controls not relevant to the instructor's job should not be in his workspace. If a number of control functions can be ganged into a single control without sacrificing whatever the instructor is required to control, such ganging is desirable.

Coding of controls can be done by one or a combination of tactual, kinesthetic and visual variables. If the instructor's station is complex, (as for example in an aircrew training simulator) attention to coding and grouping of controls with a view to reducing instructor load and error probability is likely to pay off. Instructor error in control manipulation can be expensive in training time, simulator time, and in cost of trainee morale and confidence in trainer and instructor; it may also result in faulty training. In the case of proficiency evaluation, irreparable damage can be done by instructor error in a test for which alternative forms of the test, or additional testing time, are not available.

Division of control labor between the limbs should be attempted. If the instructor is required to write comments or evaluations, provision might be made for the left hand and the feet to share heavily in control activation.

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1. A reference currently available is Woodson, W. E., Human Engineering Guide, Berkeley, Calif. 1954

The many considerations dealing with control-display ratios and control loadings should be obtained from the following sources:

Chapanis, A., Garner, W. R., and Morgan, C. T. Applied Experimental Psychology, N. Y.: Wiley & Sons, 1949.

Jenkins, W. L. Design Factors in Knobs and Levers for making Settings on Scales and Scopes (A Summary Report). WADC TR 53-2, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Swain, A. D. op. cit.

Woodson, W. E. (ed) Human Engineering Guide for Equipment Designers. Human Engineering Section, Human Factors Division, U. S. Naval Electronics Laboratory, San Diego, Calif. (University of Calif. Press 1954)

Repeater controls do, however, deserve special mention here. (Repeater controls are linked tandem to trainee controls.) Repeater controls for the purpose of teaching the trainee through manual guidance are not likely to be worthwhile, because almost no learning effects occur in this way. It is extremely doubtful if repeater controls have training value even for demonstrating the proper use of controls. When a trainee's limbs are passively moved by an outside force through a configuration which is supposed to be timed to a display, learning effects are generally negligible.

Repeater controls in a training aircraft serve a real function in reducing hazard to trainee and instructor, or to free the trainee from attention to controls while observing something else important for him to notice.

TRANSMITTING INFORMATION TO THE TRAINEE

In this section "information to the trainee" will include not only speech from instructor to trainee, but also instrumental inputs to the trainee controlled by the instructor. Such inputs may be signals about the learning process (for example, a special light signalling the trainee to scan more than he is now doing) or they may be program inputs such as emergencies, target courses, and so forth.

Speech Communcation

Direct voice communication has a number of advantages. It provides rapid feedback or guidance in the context of trainee behaviors. It is normally less distracting and requires less effort than the use of intercommunication equipment. Direct voice is of disadvantage in communicating over a distance, thus it allows the instructor somewhat less flexibility of movement than a portable microphone; it may be unsuccessful in competing with background noise; and it does not provide the trainee with practice in the use of interphone equipment if such equipment must be used in operations.

If intercom is used, arrangements should free the instructor and trainee from manual control if practicable.

If more than one instructor operates a training device at the same time, it is desirable that they intercommnnicate without any cues being perceived by the trainee.

Speech or other signals having to do with the learning process should be presented so as to minimize disruption in ongoing activities. Some kind of low-level warning that such a communication is imminent may be provided a moment or two before the message begins. Thus the trainee may prepare to divide his attention without blowing up. A two to three second foreperiod is usually optimal for simpler tasks, several seconds more if the trainee is engaged in a difficult (to him) task.

Coded Information To The Trainee

Cues artificial to the task may be used to signal the trainee to perform certain activities he has been neglecting, or provide other supplementary information. Some examples follow:

1. A special tel-light above the trainee's panel which when activated by the instructor's "scan switch" tells the trainee to "SCAN!" The placement of this light should be somewhat outside the trainee's normal scan pattern so as not to provide an "action cue" artifical to operations.

2. Wheat-grain lights for some of the more important trainee station displays. Indirect light from these lamps on certain critical trainee displays might be used by the instructor to remind the trainee to attend to them at certain times. The more such artificial lights beyond four or five (and the more they are used) the less effective they become for training.

3. The instructor flashes a correct point of aim in a non-computer gunnery device.

4. The instructor uses an over-ride switch and shows the correct "picture" on the trainee's radar scope.

5. The instructor flashes a thin beam of light or a light "circle" on the panoramic target presentation in a visual reconnaissance trainer to point out target stimulus cues.

(Note: Care must be exercised lest any of these devices provide crutches to the trainee which will, in the long run, decrease rather than increase effective learning of operational tasks.)

Freeze Switch

Consideration should be given to the training value of a freeze switch which stops and holds all training device displays, and if feasible from an engineering standpoint, the positions of all controls at the trainee's station. During such a freeze the instructor can point out specific display-control relations which the trainee should or should not be making. This arrangement has many advantages as cited under optimal conditions for Knowledge of Results (Chapter IV).

Discontinuous Versus Continuous Control Settings

In general, a multi-position selector switch is better than a continuous adjustment knob for inputs to the trainee station. Thus wind-direction and velocity usually need not be continuously variable throughout their range. A discrete number of settings reduces the instructor's load and likelihood of error.

Trouble Consoles

Training in complex devices often teaches the trainee how to detect and cope with equipment troubles, emergencies and other complex program inputs. To the extent that the instructor must not only monitor the trainee's performance but control complex program inputs to the trainee there is increasing danger of overloading so that the instructor fulfills neither purpose effectively.

One solution is to provide two instructors, one of whom controls the program of inputs, and the other monitors trainee performance.

Another solution is to provide gang or program switches and single controls which, when activated release a canned sequence of program inputs to the trainee.

Or it may be made possible for the instructor to pre-set a number of troubles at his panel, and then, provided with holding switches, release these troubles at times best suited for training the trainee during the practice session.

(The designer should again be reminded that a large number of different canned programs should be available so that trainee can get general skills at coping with a type of problem whatever the combination of conditions under which it may occur.)

Coding of trouble controls and displays may aid the instructor to differentiate troubles which the trainee should have responded to at once (red tel-light); those which warn the trainee of a developing trouble (yellow tel-light); and those which indicate an inefficiency of the man-machine system due to improper trainee action, but which is not a threat of emergency (blue tel-light).

Return to normal operations: After a trainee has performed a malpractice the equipment's return to "normal" operations should be rapid and under the control of the instructor. Not only is training time saved, but the trainee has opportunity to try making the correct response before he forgets what he did incorrectly.

Either the equipment should return to "normal" operations automatically after a certain interval of simulating a trouble, or the instructor should have vivid indication (as by flashing light) that the trainer is still simulating the trouble.

Sequence Of Trainee Error And Instructor-Controlled Inputs

There may not be automatic feedback response to trainee error. For example, the trainee may forget to open cowl flaps. It may then be appropriate that the cylinder head temperature go up. If the instructor must manually control the indication of cylinder head temperature, he should be given a special signal at his station that the trainee has neglected to open cowl flaps. A master light of trainee error may be centrally located in the instructor's station. His attention then is referred to a special "trainee error panel" on which a specific tel-light indicates the specific error.

Control Of Artificial Feedback Cues

Operational feedback may sometimes be supplemented by artificial cues informing the trainee when he is or is not successful in some performance. These cues should be intermittent, not capable of being anticipated by the trainee, and under the control of the instructor.

Control Of Continuously Changing Inputs To Trainee's Station

"A continuously changing input" may be one which literally does change from moment to moment such as an enemy target aircraft, or it may also be one which theoretically may be changing continuously, such as wind direction and velocity, but for practical purposes changes infrequently and more or less discontinuously.

Other inputs which may be on the borderline between continuous and discontinuous are enemy jamming effects, static, and other types of visual or auditory stimuli which represent noise in task programs.

If well-trained instructors will be using the training equipment, it is probably desirable to have manual controls for these inputs to the trainee available for the instructor, even if automatic or canned program presentations are also available. Flexibility is thus possible in programming for a given trainee at a given time. The instructor can keep the trainee loaded but not overloaded; he can repeat certain sequences in a program or otherwise work intensively with certain deficiencies in the trainee and not waste time with excessive training on what the student can already do successfully.

In any event, the instructor should at will be able to cut out or cut in programmed noise as a trainee input. Operational proficiency should be estimated not merely on how well the trainee performs under "representative" operational conditions, but how well he does under extreme conditions to be met in operations short of complete breakdown of (operational) equipment functioning. (It is also generally good for morale in training that the trainee's work load be near his capacity during any stage of practice. It should be remembered, however, that magnitude of load during learning is in part self-imposed by the trainee: It is determined by what the trainee is trying to do--the range and degree of error he is setting himself to avoid or reduce.)

The introduction or cessation of noise signals should not be so standardized that they become action feedback cues to a trainee during practice.

This and other problems of artificial restruction of input programs to the trainee in training may be reduced by providing the instructor with a detailed syllabus which itemizes program sequences. Flexibility permitted in the syllabus should not permit the instructor to ignore, during training, program variables or situations of major importance. In order to maintain balance in training, it may be desirable that canned or taped programs be presented in their entirety to the trainee in occasional practice sessions. Such a session might be both a training session and a stage of proficiency evaluation.

If the simulated target is operationally maneuverable, and its maneuvers are in part a response to the trainee-operator's output, a new order of design problems arises. Automatic target course generators or canned target programs become prohibitively complex or actually unfeasible from an engineering standpoint, unless the response of the trainee should be standard and predictable. In the case of aerial fixed gunnery tactics, this is not the case; the action of the trainee-operator and enemy are partly dependent and partly independent of each other. Since flexibility and judgment are required in the generation of such target courses, it seems desirable to assign to a second instructor the task of manually controlling target movement. Whether or not this control should be filtered through the simulated characteristics of the enemy aircraft is a problem related to the discussion in Chapter III, Stage of Learning and Degree of Physical Simulation, pp. 48-52.

PROVISION FOR INSTRUCTOR DEMONSTRATION OF PERFORMANCE

There are some provisions for demonstration by the instructor which will be more fruitful than others. Since one learns what one does (actually or symbolically), demonstration may constitute symbolic practice of a sort depending on the kind of communication which the instructor can make to the trainee, and the trainee's capacity later to transform symbols into action. Highly skilled pilots can learn what to do from a briefing session in which maneuvers are demonstrated by hand movements in the air. But the pilot has already learned the many component responses which can make the airplane behave in the way summarized and symbolized by the hand movement.

Demonstration Of Motor Aspects Of A Task

The instructor's demonstration to the trainee of the motor aspects of a task produces small if any learning benefits. The trainee may get some idea of timing of response with respect to other responses, or of smoothness of response, but these data may be useless when the trainee has to match the response to task cues unless he already has the response patterns in his repertory.

Like any other form of symbolic communication, demonstration may be of special help in showing the sequence of responses in a procedural task. Demonstration will tend to cut down the trial-and-error behavior of the trainee. But it may be more profitable for the instructor to give the trainee verbal guidance while the trainee himself goes through the response sequence.

In conclusion, provision for the instructor to give demonstration of motor performance is not important except to convince the trainee that criterion performance required in training can potentially be achieved on the trainer.

Demonstration Of Perceptual Aspects Of A Task

Demonstration of perceptual aspects of a task are likely to be of relatively little advantage over verbal description. There are some exceptions. The demonstration of on-target position may provide a reference for the trainee which, although subject to limitations in recall, may be of important temporary benefit. The demonstration of what a "good picture" looks like in adjusting a scope may have similar benefit. Provision may be desirable for enabling the instructor to demonstrate a "good picture" without major disruption either of practice or the instructor's monitoring of practice. If the instructor is seated beside the trainee, he can manipulate the trainee's controls directly. If he is remote from the trainee, he may be about equally as effective by slowing or stopping any program input to the trainee and then giving verbal instructions which get the trainee to manipulate the controls until a good picture, or an on-target display, is obtained.

GENERAL FACILITIES FOR THE INSTRUCTOR

These considerations deal with the conditions which promote instructor comfort, and minimize distraction and fatigue effects. They are, however, standard problems of human engineering which are thoroughly treated elsewhere. They are summarized as follows:

Seating Arrangements

Standing even for short periods of time is fatiguing. Seating arrangements should be provided. If the instructor has to be on his feet and move around a good deal, a high stool upon which he can rest briefly without hoisting himself up and down may be more desirable than a chair.

Instructor's Chair

A person who spends long work periods in a seated position deserves a chair which is both comfortable and functional. Uncomfortable contraptions such as jump seats quickly produce fatigue and may in themselves be almost sufficient for a person to get to dislike his job. (See Naval Electronics Laboratory *Human Engineering Guide for Equipment Designers*[1] for anthropometric measurements and specific recommendations for chairs.)

Disturbing Noise In The Instructor's Station

If the instructor can monitor auditory and tactual noise to the trainee's station without being continuously subject to that noise himself, less fatigue can be expected, at least over the long term. Many studies have shown that humans adapt successfully even to fairly high noise levels, but there is some evidence that the adaptation is at a higher energy cost. It should be remembered that the instructor spends his work hours, day by day, at the same job. Conditions which lessen his liability to annoyance should be sought.

Ventilation, Temperature, Humidity At The Instructor's Station

These factors will affect the instructor as they do any other operator. The NEL Guide contains information on ventilation and room temperature according to amount of work performed. Chapanis, Garner and Morgan in their *Applied Experimental Psychology* offer recommendations on temperature, humidity and ventilation.

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1. Woodson, *op. cit.*

Illumination

The illumination at the instructor's station should take into account not only that visual field, but also the field which the instructor may have to observe in the trainee's station. Marked differences in general illumination will handicap the instructor by demanding shifts in light adaptation. Direct sources of light at the instructor's station should be shielded and glare surfaces eliminated.

For general requirements of absolute illumination for various types of visual work see Baker and Grether (op. cit.).

Grounding of Equipment

The training equipment should be properly grounded so as to prevent the instructor or trainee from being shocked by static electricity or power voltages. Static electricity can be a source of considerable annoyance and distraction, and its elimination from the work-space justifies some effort and expense in design and construction.

SUMMARY OF STEPS IN DESIGNING THE INSTRUCTOR'S STATION

The following steps outline a procedure for designing the instructor's station:

Step 1. Design the trainee's station. This design includes the inputs and outputs of the trainee's station. Inputs consist of variables and channels, and programs of stimuli.

Step 2. Decide which inputs (task stimuli and knowledge of results) to the trainee should be merely monitored by the instructor and which should come under his active control.

Step 3. Decide which outputs (responses) of the trainee should be monitored by the instructor and which are not necessary for him to monitor.

Step 4. Make a time-chart of the instructor's monitoring and controlling tasks based upon the time chart of the trainee's inputs, outputs and response feedback requirements.

Step 5. Decide where the instructor should sit in relation to the trainee's station.

Step 6. Decide which monitoring and controlling aspects of the instructor's job will be done via instructor's station equipment and which will be done via direct observation of the trainee or trainee's station equipment and by voice communication with the trainee.

Step 7. Decide what specific displays and controls are needed in the instructor's station.

Step 8. Lay out the instructor's displays and controls according to optimum placement for his required functions and sequence of activities.

Step 9. Evaluate and modify the tentative design.

CHAPTER VIII
THE TRAINER AS DEMONSTRATOR OF PRINCIPLES

The performance of a job usually requires a combination of perceptual-motor skills and problem-solving or ideational skills. The learning and transfer of perceptual-motor skills requires practice; the learning of ideas and ideational skills also requires practice. Each type of skill improves more rapidly and is better transferred under efficient practice conditions than when part of the stimulus inputs and response outputs is irrelevant to the training objective. This chapter is concerned with determining what is essential and what is non-essential in the process of demonstration which uses such equipment as: charts, cutaways, animated panels and some forms of model and mock-up.

Operational equipment and complex simulators can be used for demonstration and part-task trainers. Our discussion in this chapter will be directed to devices *intended* to be used for no more than demonstration.

THE FUNCTIONS OF DEMONSTRATION IN TRAINING

Demonstrations about equipment usually show cause-effect relationships between activation of some control in the operational equipment and some output of the equipment. Intervening linkages may be shown with varying degrees of symbolism and simplification, depending on the relation of detail to job behaviors. Some principles for showing input-output relationships may be summarized as follows:

A demonstration should simplify concepts: The demonstrator may serve the function of simplifying the idea of how a complex machine or piece of electronic gear works by schematizing its linkages. Its advantage over a two-dimensional drawing is that the trainee does not have to imagine the dynamic process observed. Thus, the push-pull forces of a hydraulic system may be represented without showing the detailed components of actuators or the electrical circuitry associated with servo valves.

Eliminate details not relevant to principle demonstrated: No effort should be spared to abstract the critical action or working relationship and ruthlessly to eliminate superfluous details and non-essentials. For this reason, a good diagram or blackboard drawing may be more effective than an expensive cutaway. If a number of variables interact to affect an output (such as a bomb drop) the influence of changing each of these variables should be clearly demonstrated by a change in the output. Actual magnitudes need not be simulated in the device -- they may be shown better and more simply by equations on a blackboard.

Dramatise outputs: It is generally better to represent a "target" as a bridge or marshalling yard than as a black spot. This representation of the literal effect of an output is important not only for arousing immediate interest, but also, by being concrete, it will aid the trainee in transferring the concept to real operations. That is, he will remember it better later on.

This suggestion is not inconsistent with the previous statements about simplifying the presentation of a process, because it deals with an outcome of the process. However, if inconsistencies appear, lean towards simplification rather than realism.

Dramatize differences between old and new operations in transition training: Through emphasis and distortion special differentiation can be made between either stimulus components or response components in a new job or task which differs from one previously practiced by the trainee.

The entire demonstration should be taken in at a glance: In order that input-output relationships can be clearly understood, the scale of the demonstrator should permit a view of the complete action to be shown. On the other hand, the scale of the demonstration should not be so small that changes in outputs seem negligible or unimportant.

Levels of understanding: "Understanding" how something works is not an all-or-none matter. The understanding of electronics required for competence and interest in his job by a designing engineer may be (and is!) quite different from the kind of understanding required by the mechanic who services the equipment. The mechanic may only operate a few switches on the front of a checkout set and replace black boxes when certain indicators light up. Competent understanding of soil chemistry does not necessarily require a grounding in nuclear physics.

The term "understanding" should therefore have subscripts depending on the purpose and actions to be related to each other by each understanding. At some level of operations all theoretical understanding may become "functional" understanding -- that is, the knowledge of what does what to what. This homely phrase suggests that a level of understanding has a criterion of relevance. Electrons do not act (directly) upon molecules -- a discussion of energy changes has different levels of discourse defined by the objects which interact with each other.

The appropriate level of understanding at which the training curriculum and demonstrations should be pitched may best be determined by the structural units with which the job will be concerned and the "principles" which are directly applicable to predicting the interaction of those units. Functional understanding will be defined now by the job functions of the trainee. His understanding should be consistent with the level of operations and decision he will have to make. A man working with dangerous chemicals should know what material they will damage and the proper method of stopping their action, but need not know the atomic weight or valence of the elements which the chemical contains.

The presentation should therefore involve the smallest number of variables and their interactions which are consistent with the trainee's interests at this stage of training as well as with the job requirements and the ability levels required for that job. This simplification should result not only in training economy, but increased sense of achievement and interest among the trainees. There is another advantage in simplicity of training demands consistent with job requirements: good persons for the job will not have been screened out during training because intellectual requirements were demanded which were irrelevant to satisfactory performance on that job.

The Demonstrator As A Basis For Generalizing Information And Training

The principles of aerodynamics apply to any aircraft (except for some discontinuities as at sonic speeds) and the geometry of ballistics apply to any projectiles. The functions of at least some demonstrators is to show vividly and simply to the trainee the basic operating principles of a class of machines or equipment.

It is well known that abstract principles can usually be easier learned and better remembered through concrete examples, if the examples clearly get over the point intended.

Demonstrational devices may therefore show to a trainee getting either "generalized" training or transition training the operating principles common to a class of machines. Examples are: hydraulics, aerodynamics, electronics, servos, ballistics, mechanics, turbines.

The demonstrator, in the hands of a skilled instructor, may aid in teaching for transfer of training at the conceptual or "idea" level of job performance.

The Demonstrator As A Working Framework For Relating Separate Areas of Training

A demonstrator may be designed partly to show the relationship of one portion of a training course to another and thus serve to bind them together. Training aids especially designed for showing the various interlocking functions of a complex electronic device may serve such a purpose. In effect, it will help to unify at the conceptual and idea levels the separate blocks of information the trainee has or is learning about a system. Thus if an operational system contains eight major sub-systems, it may be easy for the trainee to forget while studying sub-system five much of what he has learned about one through four. By relating parts of knowledge to a central idea (such as the system acting as a whole) the parts themselves may be better remembered and better used.

SELECTING THE WORKING COMPONENTS OF THE DEMONSTRATION TRAINER

Decisions as to what to include and exclude in the design and construction of a training aid or demonstrator should be based principally on the job behaviors of a particular job and the ideas or mental concepts which will help get that job more quickly learned, or better done. A demonstration device should show simply what is otherwise complex to understand.

On the other hand, it is easy to exaggerate how much can be learned by demonstration. Demonstration, like other forms of guidance, may tend to cut down the range of trial-and-error of the trainee, but it does not take the place of actual practice either in problem-solving or in perceptual-motor performance. Large expenditures in glamorized demonstration apparatus (such as complex cutaways) are not likely to be justified on practical grounds. As elsewhere in training, the crucial question to be asked is: "What specifically will the trainee learn or do better on his job because of this training device?"

Before a demonstrator is constructed the question should be asked: "In what specific way does this device help the trainee above what could be shown by a crude sketch on a blackboard?" Because demonstration is usually interpreted through symbols (sentences, ideas and so forth) by the trainee, the representation may be schematized and symbolic, and still transfer to the trainee's training need.

The general questions from which training aids and demonstrators may be logically derived for training purposes include the following:

1. What human inputs to the machine are required by the job?

2. What non-human inputs go into the operational equipment?

3. What outputs of (and within) the equipment affect job outcomes?

4. What are the main transmission linkages in the operational equipment between the inputs and outputs which are affected by the operator's job?

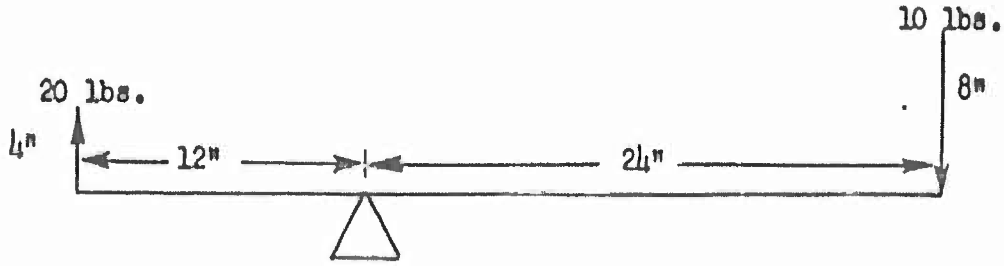
A Sample Problem

Let us take a sample problem and sketch our way through it.

We have examined the job operations and tools of an engine mechanic and recognize a mechanical principle which he must use (wittingly or otherwise) in performing his job. This principle is also an important one to the design of the equipment on which he works. The second factor is less important than the first, but it is worth bearing in mind.

Many job demands require the concentration of force by use of tools. We see that the use of screw-drivers, jacks, crowbars, and a number of other tools have in common the principle of "leverage." We abstract the common features of activities performed by these tools. They include a fulcrum, a rigid member, a point of applied force on the member and a point of force applied to an object. The factor critical to the force relationship is the relative length of the rigid member from fulcrum to object and fulcrum to hand.

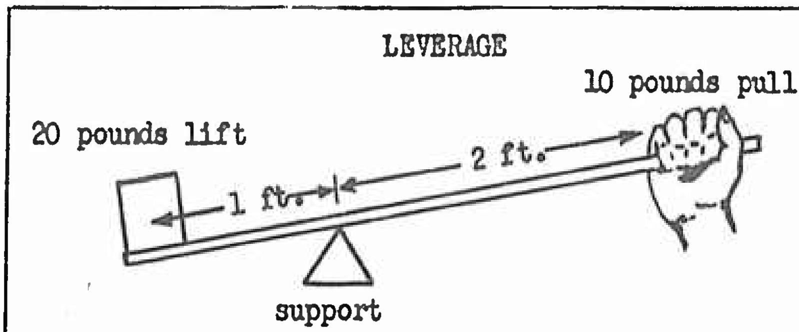
We may represent the principle in the classical test-book diagram thus:



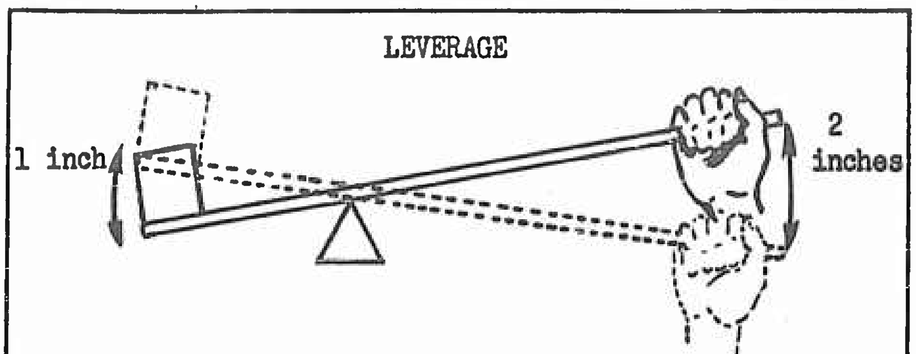
Schematic Diagram of the Principle of the Lever

Unless the trainee is quite intelligent, or has already had a course in elementary physics, he will not be able to translate this abstract diagram into experience, real or imagined. It won't make "sense" to him because it lacks sensory implications. Furthermore, we have overloaded the diagram with too much information for a simple grasp of meaning.

Let's introduce concrete elements into the diagram and instead of analyzing mechanical advantage in one diagram take one variable at a time.



What is gained is the ability to lift more weight



What is lost is the extra distance travelled
(But this is usually not important.)

Avoid unnecessary precision in conveying an idea: Since the mechanic will not be required in the course of his job to solve equations beyond the crude level of determining "more than" and "less than" it is possible that an attempt to include equations on these diagrams might set up negative reactions. If the matter of learning to solve the equation is considered of sufficient importance (and the job requirements probably would not justify it) a moving model might be constructed with variable fulcrum, balance weights, and distance scale. No more than two fulcrum positions, three weights and two distance indications on each distance scale should probably appear in order to keep the relationships dramatically simple, and in order to reduce the cost of manufacture by requiring coarse precision.

Show varied examples from the job: The next step in the series of diagrams would consist of showing the ways in which the mechanic applies the principles of leverage by using various tools, and using them in various ways. Each picture, as of crowbar, screw-driver, wrench, wing-nut, and so on, should show the elements of applied force, fulcrum position and exerted force. Separate diagrams might be needed to schematize an applied and exerted force on the same side of the fulcrum.

Representing Transmission Systems

If the trainee's job calls for action or decisions based on trouble-shooting the equipment, the transmission linkages or loops within the machine will need to be represented. In the interests of economy, simulation of the actual mechanisms or portions of the system need not go within those components whose inputs and outputs will provide the information needed for diagnosis. That is, if the mechanic or operator in the course of his job will not conduct actual operations within a given black box, but will have to decide whether or not this box is satisfactory for operations, the input-output functions of this box in the trainer may be simulated by mechanical or electrical means other than those used in the operational equipment.

Whether or not a three-dimensional mock-up (non-functional) of a complex equipment is as good a general teaching device as a functional or actually working demonstrator is difficult to say. It is even more difficult to say whether a functional demonstrator is worth the additional cost over a mock-up in terms of training advantage. It is probably the skill of the instructor which is the critical variable. Certainly the prediction of the probable usefulness of a demonstrator cannot be made without reference to a syllabus on its use in training.

A demonstrator used in teaching trouble-shooting should allow malfunction symptoms to be represented as they may appear to the operator or mechanic or both. The source of the symptom should be traceable. If various malfunctions may give rise to similar or identical symptoms, the linkages between the various possible causes and the effect should be clearly manifest.

The foregoing discussion suggests that two sets of information will be necessary prerequisites to the adequate design of a demonstrator for training in trouble-shooting. One set of information will consist of what the operator or mechanic has to do on his job (action or decision) involving checking, adjusting, repairing, or replacing the equipment or parts of it. Another set of information will consist of malfunction symptoms characteristic of the operational equipment. The representation of the linkages between symptoms and symptom sources according to job behaviors then will define the essential components of the demonstrator for trouble-shooting.

Coding

The display of transmission systems and sub-systems should, of course, enhance the differences between those parts of the system which are functionally independent of each other, and should show, by suitable coding, the relations of parts of the system which are interdependent. Coding should be consistent throughout the demonstrator and, if possible, consistent with coding used in the trainee's texts, training manuals, and so forth. Ideally the display should permit instantaneous perception of the entire set of operating relationships being presented at one time. These relationships should require minimum time and effort to switch from one to another. The relationships should be readily observable by all the trainees in whatever group is working at the demonstration. The more time required (beyond a few seconds) to get a demonstration under way, the greater the boredom and loss of learning motivation. Besides loss of interest, there is also loss of continuity and carryover of ideas if there are time lags between one portion of the demonstration and later portions.

Recommendations for Use

A syllabus should be prepared to accompany each training aid. This syllabus should clearly identify the job behaviors related to what the training aid is intended to teach. Suggestions should also be made as to how the instructor can test whether the trainee has acquired and will transfer the job knowledge obtained from the demonstration trainer.

CHAPTER IX
OUTLINE OF STEPS IN DESIGNING A TRAINING DEVICE

Introduction

The following pages are a summary of the steps to take in the systematic design of a training device. It will be reasonable for the designer of training devices to have the collaboration of a specialist in the psychology of training and the methods of task analysis summarized below.

How to go about performing these steps has been described in summary fashion in the preceding chapters and in greater detail in the references cited at the end of the chapter.

1. Prepare a task analysis of the man-machine job

The logical first step in the design of a training curriculum or of a training device is to determine what the operator in the man-machine job has to do. This step follows from a determination of the input and output channels of the man-machine system and the role played by the operator (or mechanic, if it is a maintenance job being studied) in these linkages or system functions. Determine the quality variables, tolerances and standards required of the man-machine team as best as can be done.

Distinguish procedural, discontinuous tasks (such as switch-turning) from continuous or tracking tasks such as aiming a weapon or driving a vehicle or craft.

Itemize tasks according to sequence, and those actions performed at or about the same time.

Within each task isolate the behavioral steps and identify the critical discriminations (perceptions), decisions, memory storage, and human motor outputs required of the operator in operating and monitoring the equipment. Of special importance for each task, and often for each behavior, is the Likely or Characteristic Error or Malpractice which can be expected of it. Both the "Likely Error" and its behavioral background may be derived from considerable study of the task, the work environment, sequence of behaviors and anticipations, and from wide experience of the analyst in behavior patterns and habit systems. Training obviously should be directed against error tendencies, some of which may be well buried, and which may arise only in the development of higher orders of skill by the trainee and operator.

Determine the concrete "programs" or environmental variables and conditions in which each task will be performed in operations.

Prepare a time-base chart of mission cycles or maneuver cycles. Onset, duration and overlapping of behaviors should be represented on the time-analysis chart of behaviors. This chart will show when the operator is heavily loaded, the number and kind of channels of information to which he must respond, the signals which he must anticipate, and his demands in reaction time.

The preparation and interpretation of such a chart will probably require the aid of a specialist in task analysis and human engineering. [1]

2. Select the tasks which are to be trained

The job segments, tasks and programs for which the trainee is to be trained on a given device will need to be selected. A number of these decisions may be relatively arbitrary. This selection should, however, be aided by a human engineer who can point out dangers to training efficiency by some selection of tasks from the total task context, while he may suggest training device economies by other selections of tasks and programs for a given trainer.

Part-task trainers can be efficient and very economical in a training program, but their design from the human engineering standpoint requires a high degree of sophistication in the area of human learning and transfer. Their limitations should also be indicated so that they will not be used inappropriately. (See Chapter III.)

3. Decisions on degree of training expected on tasks

Having decided what the trainer is to help teach, we should decide how well the trainee should be able to perform it by practice on the trainer. Degree of training is important as it relates to principles and considerations as given in Chapter III, "Stage of Learning and Degree of Physical Simulation." A trainer may be very useful even if it trains some tasks to less than operational adequacy. The human engineer should assist the design engineer and delegates from operational and training agencies in making these decisions.

4. Assumptions about the trainee population

Next we will want to know what kind of trainee will be using the trainer. That is, what relevant skills, knowledge and abilities will be brought into the training situation. Estimates of trainee load will help put trainer needs into perspective.

5. Assumptions about instructional personnel

It is helpful to know what skills and abilities can be expected of the instructors so that what the instructor is not able to do, the equipment can attempt to do for him. For example, will the instructor have skills in the operational equipment for which training is intended? Will the same instructor teach the trainee in the trainer and on the operational equipment? Chapter VII, "The Instructor's Station," explains why this knowledge is important for design of the trainer.

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1. See Appendix I and II for samples of task analysis pages and time-charts.

6. Assumptions about integration of synthetic and operational training

We can expect somewhat different transfer of training depending on whether the trainee alternates days on the synthetic trainer and on the operational equipment, or whether he completes an entire phase of training on the trainer and then gets into operational equipment. It is usually easier to train for transfer when the two situations are side-by-side, and this fact may alter the demands placed on training equipment hardware.

7. Integration of assumptions and stipulations

Experience shows that it is very difficult to get responsible individuals to agree or become committed to any of the foregoing stipulations about a proposed trainer. Nevertheless, without a stipulation as to how a tool is going to be used and for what purpose, the design of a tool or instrument is bound to come out of a crystal ball. First to design some device and then to attempt to invent ways in which to put it to practical use invites all-around inefficiency.

The designer should therefore get comments on the foregoing points established explicitly. Without them he is a cousin of the engineer who was asked to "design a device which would train protoprincia to fluticate." That is, without clear-cut definitions and operational statements of objectives, the designer suffers an unreasonable handicap in the invention of training devices.

8. Abstract hardware requirements from the relevant tasks

This step will consist of no more than an enumeration of equipment items such as displays and controls which appear in the description of those tasks selected for training. Strictly speaking, programs are not hardware items, but hardware provisions will need to be made to generate them; thus they should be enumerated also. Programs will include samples of overall time-sharing of tasks included in the training curriculum.

Accessories will include seats, instrument panels and other hardware which will support the trainee, the instructor and their operations.

Scoring requirements -- each control is at least potentially subject to trainee error. In addition, there may be other forms of inadequate trainee response which will be revealed in task analysis, especially if information about characteristic trainee and operator error and malpractice is available. By setting down scoring requirements at this time, no statement is necessary as to whether scoring is to be made by special equipment, or by direct observation of the instructor.

Note: The abstracting of hardware requirements is applicable to any trainer, from training aid, or demonstrator, to a simulator. Since a "simulator" is a copy and not an "abstract" of the operational device, obviously the physical configuration of the work-space will be copied.

The list of controls and displays will, however, be helpful in the next step of specifying the functional characteristics to be designed into them.

9. Integrate task analysis data, training stipulations and hardware requirements into specific recommendations for the training device.

a. The trainee's station

This step now goes from a statement of requirements to the particulars of what will be presented to the trainee in the form of training-space configurations; control-display intersections; knowledge of results presentations and scoring; and specific programs and conditions of practice. The development of the trainee's station will generate the principal requirements of the instructor's station. These requirements consist mainly of monitoring the inputs to, and outputs from, the trainee's station, and the control of inputs to the trainee's station. (Refer to the schematic diagram of the Instructor's Station, Chapter VII, page 100.)

A convenient format for setting down each item of equipment recommendation will include the following categories:

A. Title of Equipment Item

B. Physical Properties Recommended

C. Functional Properties Recommended, Including Statement of Tolerance Value

D. Use Recommendation

E. Rationale for the Recommendation

In jobs which call for rather straightforward sequences of operations (such as bomb-handling and loading) some short cuts may be suggested. A group of tasks or actions which are performed at about the same time in some related operation (such as bomb-loading into aircraft) can be grouped into what may be called a job segment. Specify the operational equipment required for these tasks or the job segment. Then in parallel columns specify the requirements of training equipment which will provide essential practice on the critical discriminations, decisions and human motor responses involved in the tasks. Indicate also how knowledge of results or indications of response adequacy will be presented to the trainee (as through the inspection and comments of the instructor, or instrumentally).

b. The instructor's station

The requirements of the instructor's station will be generated from the requirements of the trainee's station. Hardware for meeting the requirements of the instructor's station may be devised. The organization of the hardware into the instructor's work space is a problem of human engineering of operational equipment for which the reader is referred to other sources.[1]

10. Checking the adequacy of the preliminary design from a human engineering standpoint

Many steps have intervened between the identification of the man-machine system requirements and their quality standards and tolerances, and the plans for the training device. When these plans have been prepared, it may be helpful to refer again to the requirements imposed on the man-machine team in terms of program inputs and work outputs. Take into account the variables in the quality or performance standards. Match each of these variables with actual practice afforded the trainee under the range of programs provided by the training device. Check the adequacy with which the trainee is given knowledge of results. This knowledge of results should direct him efficiently towards learning to meet the quality demands of the system.

Refer also to the restrictions in degree and kind of task stipulated for training by the device.

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1 Baker, C. A., and Grether, W. F. Visual presentation of information. WADC TR 54-160. Wright Air Development Center, Air Research and Development Command, Wright Patterson Air Force Base, Ohio. 1954.

Chapanis, A., Garneri, W. R. and Morgan, C. T. Applied experimental psychology. New York: Wiley and Sons, 1949.

Tufts College handbook of human engineering data. (2nd Ed.) SDC Tech. Rpt. No. SDC 199-1-2, SDC, ONR, Port Washington, N. Y. 1951.

Woodson, W. E. Human engineering guide for equipment designers. Berkeley, Calif: Univ. of Calif. Press, 1954.

Note: The Woodson reference has an excellently arranged bibliography of up-to-date reference on representative problems.

When all these matters are taken into account, suggestions for modifying the tentative plans for the training device may occur. Improvements should aim not only to bring the trainee more effectively to the operational skill but at cutting the cost of the training and the training device.

11. Preparing detailed instructions for the use of the training device.

It is reasonable that the considerations which go into the design of the training device should be reflected in the way it is used in training. Many examples can be shown of the manufacturer's product being misused in purposes not intended for it. Other examples can be cited in which the product's capabilities were not exploited because they were not known by the user of the product.

The designers and manufacturers, aided if possible by the training personnel who framed the need of the training device, should prepare a detailed instructional syllabus. This syllabus may be developed around the task, job segments and programs for which training is intended on the device. How to use the device in accomplishing the training objectives should be incorporated in the manual in the form of detailed, concrete, "how-to-do-it" instructions. Obviously these instructions supplied to the user of the device will not rule out changes and improvements in use derived from experience with the equipment. They will, however, tend to insure that the intent of the designer will be realized.

The following reports cover in detail the steps summarized in this chapter:

Miller, Robert B. A Method for Man-Machine Task Analysis. WADC TR 53-137, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Miller, Robert B. Human Engineering Design Schedule for Training Equipment. WADC TR 53-138, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Swain, Alan D. Guide for the Design and Evaluation of the Instructor's Station in Training Equipment. WADC TR 54-564, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Miller, Robert B. A Method for Determining Human Engineering Design Requirements For Training Equipment. WADC TR 53-135, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

Miller, Robert B. Handbook on Training and Training Equipment Design. WADC TR 53-136, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, 1953.

These references can be obtained through the Pyschology Branch, Aero-Medical Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Concluding Comment

It should be re-emphasized that these chapters have been devoted to the problem of designing training devices with minimal characteristics necessary to give the trainee the knowledges and skills required for successful performance on the job--or at least some portion of these skills and knowledges. The success of a training device should be measured by its efficiency in training the skills intended, its transfer value to operations and its economy. The latter has significance not only in dollars but in developmental effort, and in the larger quantity of training items so urgently needed for practice without which no skill is acquired and perfected. Furthermore, engineering simplicity may decrease down time and maintenance, and increase overall reliability of the device, a virtue of critical significance to training schedules.

BIBLIOGRAPHY

For a fuller treatment of practically any topic discussed on previous pages the reader is referred to the parent volumes from which the present report is drawn. Each of these volumes contains a reference bibliography. "The Handbook on Training and Training Equipment Design" contains both general and topical bibliographies which should be consulted. Space forbids the repetition of these bibliographies here. Furthermore, since much of the content herein is a condensation and synthesis of widely scattered reference material, it is felt that a "selected" bibliography here might be more misleading than helpful.

Appendix I

Sample Task Analysis Page

TASK ANALYSIS
Feedback Skill

Job: Driving 1954 Oldsmobile Hydramatic

TASK Tracking toward a variable aperture: Three rates problem (Passing a car with an oncoming car in the passing lane).

DISPLAY

Problem: Path ahead with oncoming car; competing car ahead and to the right. Assume competing car will not accelerate.

Critical input variables:

(1) The absolute rate of competing car (X):
(2) The absolute rate of oncoming car (Y); cars of variable size and speed.
(3) The absolute momentary distance between X and Y.

Critical stimulus variables:

(1) Absolute visual size (visual angle) of approaching car at given instants down to and including unsafe passing distances (distance estimation).
(2) Textural detail of oncoming car at given instants of approach (uncertain cue value for distance estimation).
(3) Position and size of oncoming car relative to aerial perspective of roadway at given instants of approach.
(4) Rate of change of variables (1), (2) and (3) taking into account combined approach motions of oncoming car and operator's car.
(5) Knowledge (memory) of acceleration potential of operator's car at that speed.

Programs and noise variables:

(1) Illumination: Daylight, night-time, dusk, road glare, non-glare.
(2) Atmospheric condition: Clear, moderate rain, light mist.
(3) Width of roadway: Sample of 24' two-lane roadway, and 18' two-lane paved roadway to be found.
(4) Size of oncoming car: Standard car size (Ford, Buick); small car size (Nash Rambler); large car size (two-ton truck).
(5) Rates of motion: Sample combinations of oncoming rates and competing car rates of 30 to 80 mph.
(6) Subjective conditions: Stress from anxiety about collision with competing car (X), or running off roadway; worry that competing car will increase speed while being passed.

DECISIONS Pass now or pass later.

CONTROLS

Description: Accelerator, steering wheel.

Activation: Steering wheel - use steering to wheel turn ratio characteristic of operator's car. Introduce maximum play in steering allowable in State inspections.

(Continued on next page)

	Accelerator: Hydramatic arrangement - for rapid access of power, press all the way to floor-board past a resistance detent.
Action:	Accelerator response cited drops transmission from 4th to 3rd gear below 68-72 mph. More power from faster engine-to-wheel ratio.

FEEDBACK Cues	Same as display, but as X, Y and operator approach, the success of the solution or lack of it becomes more apparent.
Time delay	Function of acceleration rate of operator's car.
Criterion of response adequacy	Getting back into right lane with "safety margin" (50' plus) depending on speed. (Better criterion would be in terms of time between turning in to right lane and collision: 5 seconds.)
Critical values	Collision course perceived imminent
Corrective action	Brake and return to right lane; ditch on left side

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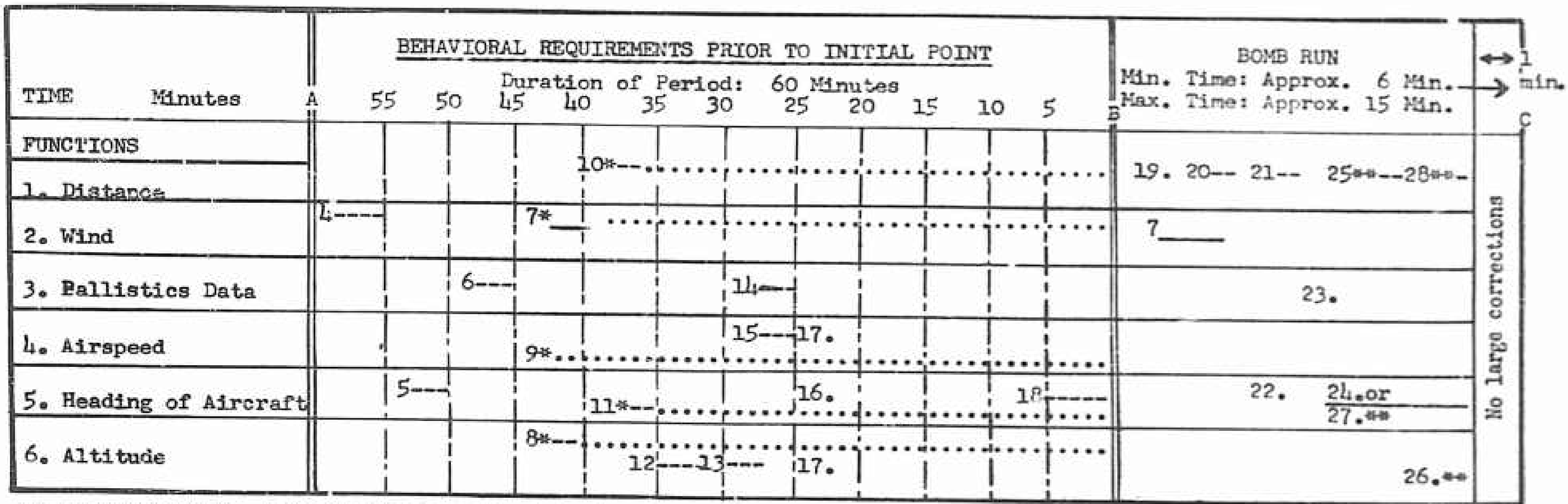
CHARACTERISTIC ERRORS AND MALFUNCTIONS	(1)	Getting too close behind X before accelerating and passing X.
	(2)	Failing to take into account slight grade.
	(3)	Failing to take into account cars behind 0 which may prevent return behind X in emergency.
	(4)	Not returning to right path as soon as safe to do so.
	(5)	Attempting to return to right path too soon.

Appendix II

Sample Time Chart From A Task Analysis

TIME CHART
Job Segment: Radar Bombing



EXPLANATORY NOTE: This chart shows the behavioral requirements involved in bombing a target from a point of origin (located one hour's flying time from the initial point) to the bomb release point. Time estimates for the requirements are based on an assumed airspeed of 350 knots. (NOTE: This chart was taken from another report in which this content was given suitable context.)

Explanation of Symbols

. A period indicates that the task is of very short duration (seconds).

*... An asterisk indicates that the task is regularly undertaken at this point, but subsequently may be accomplished at intermittent intervals during the period indicated by the dotted line.

** A double asterisk indicates those tasks not regularly required but at times essential to job success.

--- A dash line denotes a procedural task.

___ A solid line denotes a continuous task.

A - POINT OF ORIGIN

B - IP (INITIAL POINT)

C - BOMB RELEASE POINT

Arabic numerals designate tasks. Task key is on the following page.

Behaviors indicated by Arabic numerals

1. Set in offset aimpoint coordinates. a/
2. Agree with pilot on airspeed to be maintained on bomb run. a/
3. Agree with pilot on altitude to be maintained on bomb run. a/
4. Complete tracking check.
5. Complete steering check.
6. Complete bomb release check.
7. Determine wind direction and velocity (tracking stationary aimpoint).
8. Measure altitude of aircraft.
9. Check airspeed of aircraft.
10. Determine and plot fix.
11. Check heading of aircraft.
12. Measure altitude over terrain of known elevation.
13. Correct radar altitude reading for altitude over target.
14. Derive and set Trail and Time of Fall into Ballistics Computer.
15. Ascertain accuracy of airspeed indication on ID168.
16. Set in Mag Var of Target.
17. Advise pilot and engineer of IAS and PIA to be held on BR.
18. Execute procedure turn (by pilot).
19. Set in coordinates of distance from IP to target.
20. Identify target on scope.
21. Confirm target identification using Offset switch.
22. Request pilot to follow steering meter.
23. Set necessary switches for bomb release.
24. Track target or offset aimpoint to release point (no large corrections after 1 minute to go).
25. Switch to Offset and identify offset aimpoint on scope.
26. Reset Altitude for aircraft altitude above offset aimpoint.
27. Track offset aimpoint.
28. Check for possible identification of original target. If target identified, perform 13 and 24. (Repeat 28 often as time permits for synchronization on target.)

a/ May be done prior to take-off or at any time prior to the initial point.

SUBJECT INDEX